

MOTIVE POWER BATTERIES

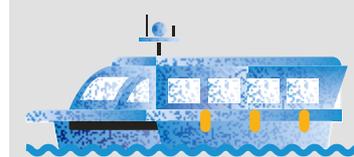
BATTERY TECHNOLOGY FOR
MOTIVE OFF-ROAD APPLICATIONS



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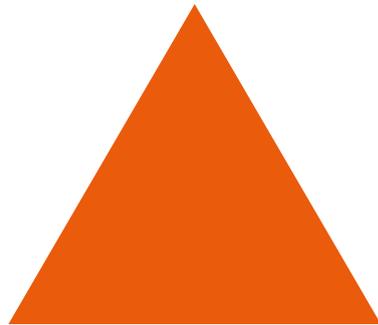
EUROBAT

ASSOCIATION OF EUROPEAN AUTOMOTIVE AND INDUSTRIAL BATTERY MANUFACTURERS

EUROBAT is the association for the European manufacturers of automotive, industrial and energy storage batteries. EUROBAT has 51 members from across the continent comprising more than 90% of the automotive and industrial battery industry in Europe.

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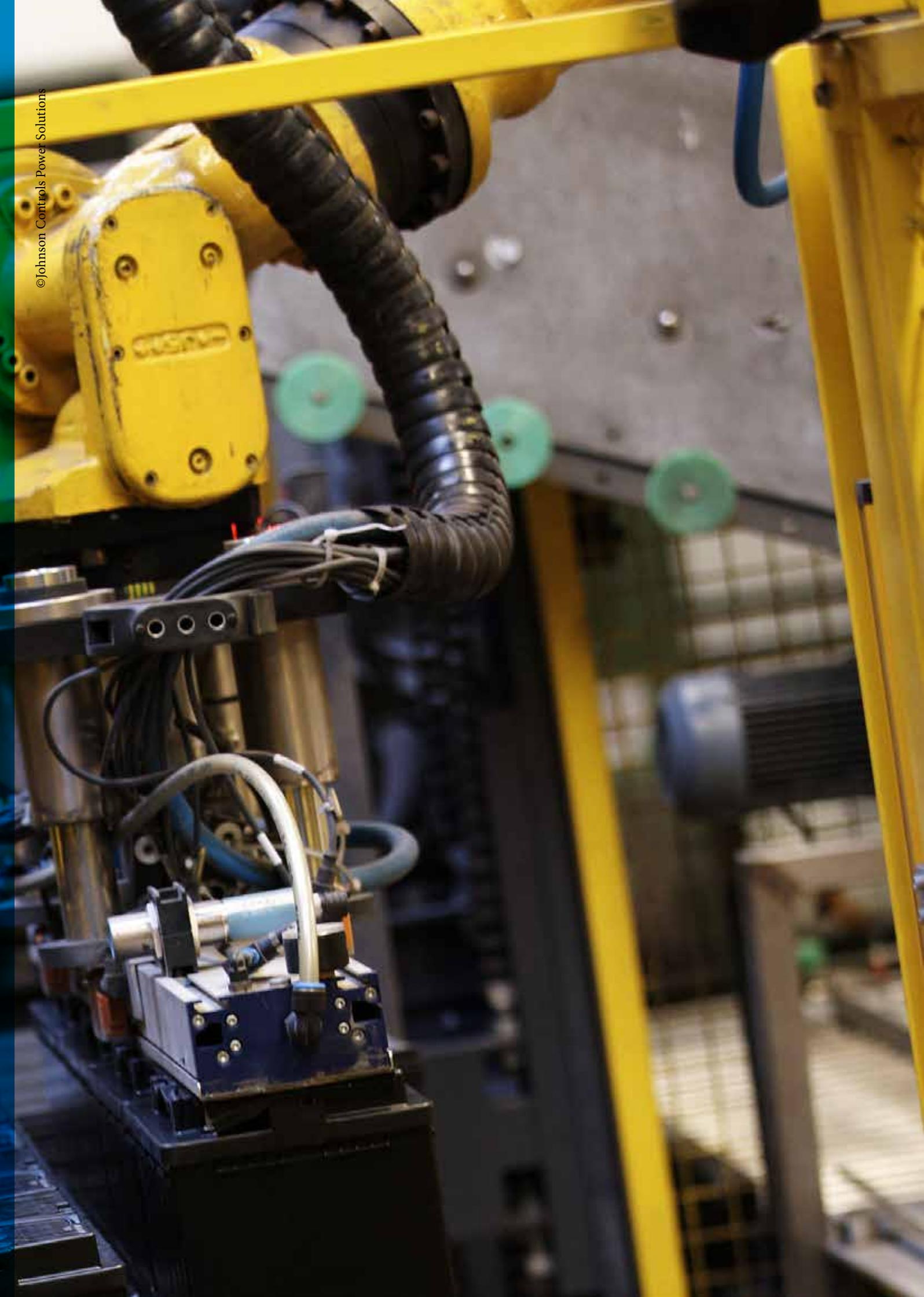
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Executive summary of the report

Batteries were used to provide traction power from the first moment after their invention. In fact, the construction of the first electric motors and rechargeable lead acid batteries both fall into the 1800's. In the field of motive power, progress in energy storage comes hand in hand with new machinery design which leads to higher productivity at lower human and environmental cost in industry. Thanks to a series of innovations in their chemistry and design maintenance free, batteries have become increasingly safe and more environmentally friendly.

The electrification of the motive power sector is driven by many factors. Battery technologies for motive power applications have developed and improved over the years. Apart from reducing CO2 emissions, using motive power batteries can also drastically reduce noise emissions. Batteries can help to decarbonise the European energy mix by efficiently storing electricity generated from renewable energy sources.



2 Introduction

With this Motive Power Batteries report, EUROBAT aims at increasing the understanding of the importance of this sector. Motive power batteries (or traction batteries) are used in off-road applications where the battery energy is used to produce motion. One of the most well-known applications is the electric forklift but there are a variety of other applications where motive power batteries are used.

2.1 What are Motive Power batteries ?

The great variety of motive power applications are covered by different battery technologies, which all have their own specifications to ensure all the specific needs of applications are covered. Batteries are the most common technology to power electric or hybrid electric motive applications because they have the ability to be adaptive to the application. On the other hand, also regulators have driven the innovation in the sector by always demanding the highest environmental, performance and safety standards. Indeed, batteries have developed to maintenance free, safe and more environmentally friendly.

There are a variety of IEC and EN battery standards existing related to performance and safety aspects. Indeed, the Motive Power battery sector is already well-established. The total installed capacity of motive power batteries in Europe amounts to more than 20 GWh. This is many times larger than the installed battery energy storage capacity, which is less than 1 GWh worldwide, or the deployed electric and hybrid vehicles, which are still quite limited. Moreover, annual sales in Europe already exceed 6 million batteries per year.

As an example, we have a closer look at the orders of forklifts with internal combustion engines (ICEs) versus electric forklifts. Electric forklifts have the advantage of having the capacity to perform without CO₂ emissions.

Moreover, since there are no exhaust or engine noise, these forklifts produce less noise



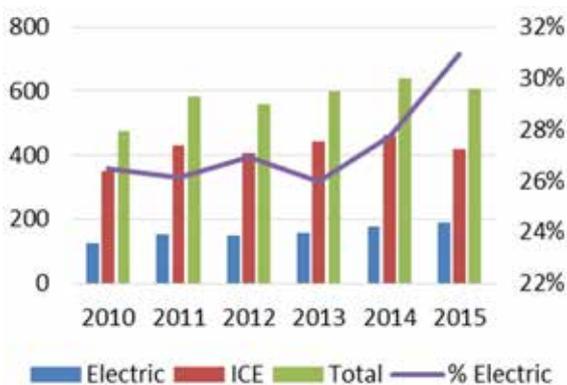
than ICE forklifts. The World Industrial Truck Statistics give for 2010-2015 for ICE and electric lift truck orders in the World and Europe clarify that indeed the trend towards electrification is taking place.

Moreover, it is clear that the percentage of electric lift truck orders in Europe is considerably higher compared to the percentage electric lift truck orders worldwide.

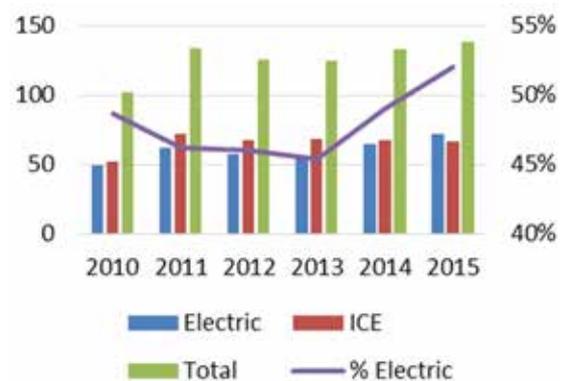
The graphic below illustrates the great variety of applications that are already using motive power batteries.

Chapter 3 provides some background on the different technologies underpinning different motive power batteries. It describes how these technologies have developed over time and continue to improve.

Chapter 4 explains how motive power batteries – and the electrification of the motive power market – relates to EU objectives and policy.



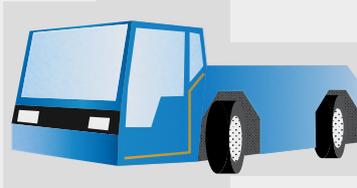
ICE and Electric Lift truck orders in the world - Source WITS Data



ICE and Electric Lift truck orders in Europe - Source WITS Data



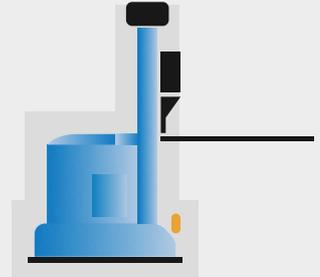
2.2 Applications of Motive Power batteries



GROUND SUPPORT EQUIPMENT



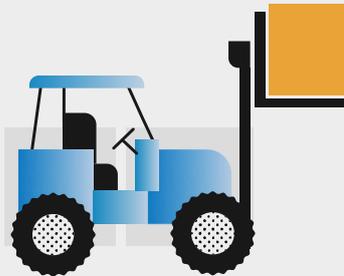
MEDICAL WHEEL CHAIR



AUTOMATED GUIDED VEHICLES (AGVS)



CLEANING



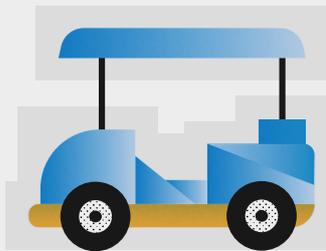
OTHER MATERIALS HANDLING



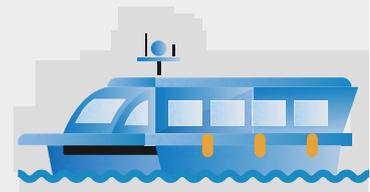
MINING



ELECTRIC OR HYBRID ELECTRIC FORKLIFTS



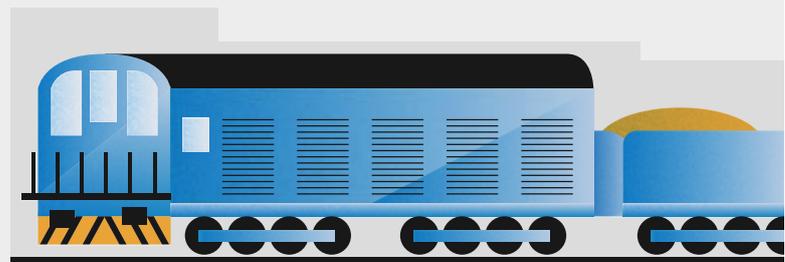
GOLF CARTS



ELECTRIC INLAND VESSELS



CONSTRUCTION/AGRICULTURE



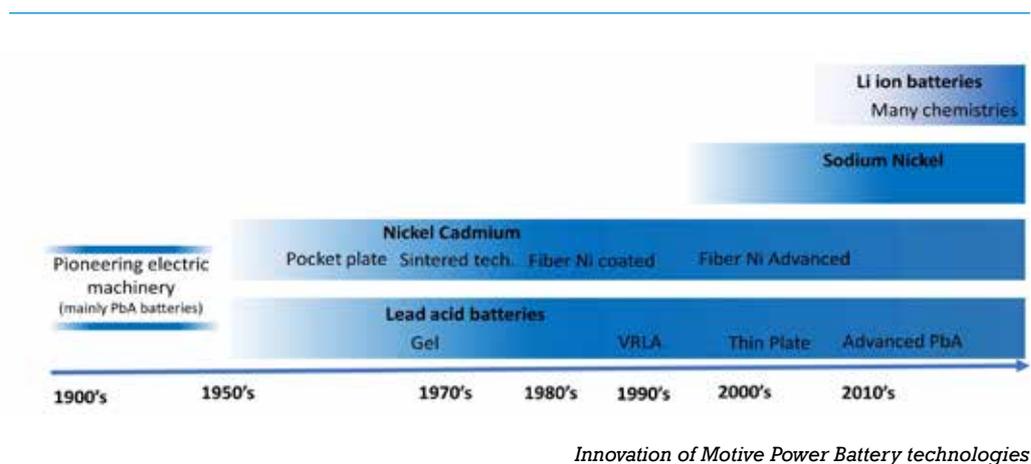
RAILWAY APPLICATIONS



3 Technologies of Motive Power batteries

A variety of battery technologies can be used for different motive applications. These technologies can be split in four major families: **lead-based batteries, lithium-based batteries, sodium-based batteries, nickel-based batteries.**

All these technologies have their own specific features that are fit for specific types of applications.



3.1 Lead-based battery technologies

FLOODED LEAD BATTERIES: CONVENTIONAL FLOODED

Flooded batteries come in the widest variety of shapes and sizes due to their widespread usage in a multitude of industries and applications. They are the most commonly used batteries on the reserve power (standby) and motive power (cyclic) markets today. Flooded batteries are very reliable and can survive in harsh environments. Unlike valve-regulated lead-acid (VRLA) batteries flooded batteries do not recombine hydrogen and oxygen to produce water internally. As a result,

flooded batteries require more maintenance than VRLA batteries. For example, distilled or deionised water has to be routinely replenished to make up for the moisture that is lost during the production of hydrogen and oxygen.

Flooded Lead Batteries in a nutshell:

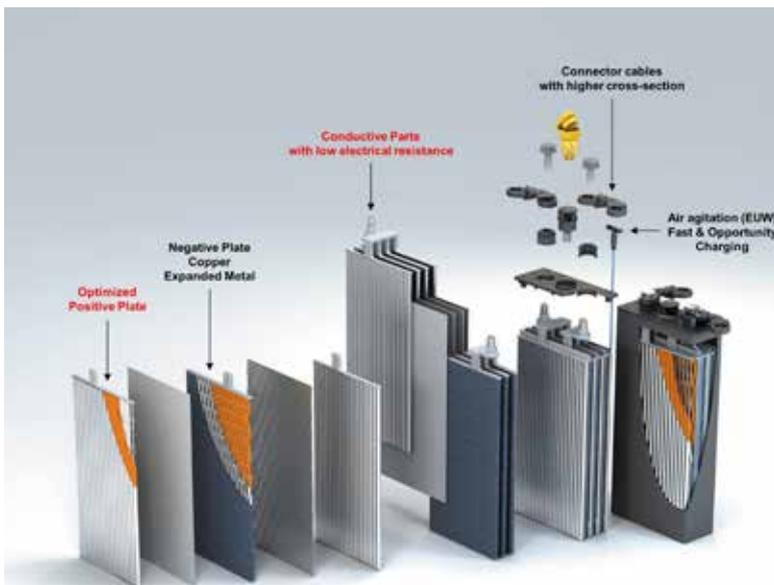
- Din & BS footprints
- Proven long life
- Good ability to recover from abuse
- Better indication of battery's health via visual inspections
- No dependence on pressure vents
- Typically built larger (more Ah – up to 4000 Ah) than VRLA
- Less sensitive to heat issues
- Electrolyte acts as “heat sink” and space between cells helps with heat dissipation
- Ability to replenish lost moisture due to gassing by adding distilled or deionized water

FLOODED LEAD BATTERIES : ENHANCED FLOODED

Even a well-established battery system like lead-acid has to answer the challenges of modern times: The number of shipment services in intralogistics is constantly increasing and material handling trucks are equipped with powerful three-phase motors as well as energy-recovery systems. Additionally also the heavy duty trucks with internal, fossil fueled, combustion engines are being converted to electric which is a real challenge in terms of power demand and application conditions. Moreover there is a clear trend for multi-shift applications on wide-front requiring fast and opportunity charging to maximize uptime. As a consequence, the demands on traction batteries with regard to performance and efficiency are rising constantly. In response to these demands, enhanced flooded lead battery systems have been developed to optimise the opposing attributes of power, efficiency and lifespan. Improvements have been made possible by combining proven technology with new materials and concepts. Essential characteristics of enhanced lead batteries are low internal resistance and significantly improved utilisation of the active mass.

The advantages of these improved lead batteries for fleet operators and users of material handling trucks are clear. Greater available energy and more power extends the running time of the truck, while reduced heat generation contributes to longer battery lifespans. In addition, lower heat generation feeds into greater energy production and correspondingly lower CO2 emissions.

Compared with standard lead battery systems, enhanced lead batteries are capable of fast charging (providing appropriate charger infrastructure is available), which again increases the availability of the battery.



Enhanced Flooded Lead Batteries in a nutshell:

- DIN footprints
- Ultra-high Power
- Long operating times
- Exceptional service life
- Fast and opportunity charging
- Stays cool in extreme applications
- High capacity at low temperatures

Enhanced traction cell - TCSM

MAINTENANCE FREE LEAD BATTERIES (VRLA): GEL & AGM (ABSORBANT GLASS MAT)

Valve-regulated lead-acid (VRLA) batteries are classed as maintenance-free models and can be divided into two categories based on the technology they use:

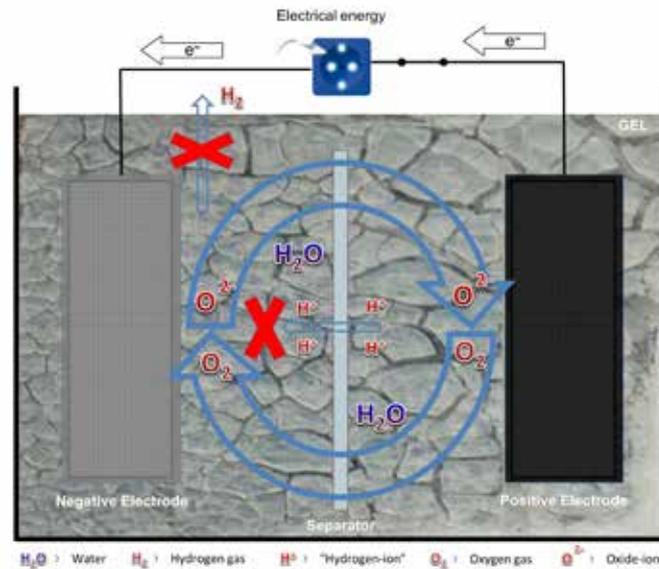
- VRLA gel
- VRLA AGM (absorbed glass mat)

Neither type requires any water refilling, with the significant advantage of reducing maintenance requirements to inspection and cleaning only.

VRLA gel batteries are particularly robust and are used as standard in material handling, cleaning and mobility applications.

VRLA AGM batteries are most commonly used in stationary applications like data centres.





Recombination” process inside GEL batteries prevents the decomposition of water

VRLA batteries function in an almost identical way to standard lead batteries, but with the electrolyte fixed either in a gel or an absorbent glass mat. As a result, acid spillage is practically impossible, and the release of charging gases is so low as to be insignificant. This due to the so-called ‘recombination process’ which actively prevents the decomposition of water into hydrogen and oxygen. Basically it is a closed-loop circulation of oxygen species between the electrodes which overcompensates the electrolysis of water.

VRLA gel batteries have now been fulfilling an ‘install-and-forget’ role for decades. They are typically used in light- to medium-duty applications because of some constraints relating to their energy capacity and charging time. Due to their high reliability and ultra-low gas emission, VRLA batteries are used to power electric wheelchairs, cleaning machinery for hospitals, and hand pallet trucks in supermarkets.

VRLA Gel Batteries in a nutshell:

- DIN & BS footprints
- Ultra-low emission of charging gases / no acid aerosoles
- Maintenance-free
- Absolutely safe & user-friendly
- Gelled electrolyte acts as “heat sink”
- Robust and reliable

Thin-Plate-Pure-Lead (TPPL) products are valve regulated lead-acid (VRLA) batteries made with absorbed glass mat (AGM) construction. VRLA absorbed glass mat (AGM) batteries use recombinant technology.

The oxygen created at the positive plates recombines with the hydrogen generated at the negative plates to create water and simultaneously prevent water loss. AGM batteries absorb the electrolyte in a fibreglass mat separator. An integrated pressure vent aids oxygen recombination and reduces water loss. The porous fibreglass material is used to separate the plates, retain electrolyte at the surface of the electrodes for electron transfer, and allow oxygen migration. High grade acid is used in conjunction with high purity virgin lead for the grids, active materials, and current collectors. The plates are thin, which allows more plates per available volume relative to traditional lead-acid batteries and faster charging.

Markets and applications served by VRLA AGM batteries include telecommunications; cable TV; emergency lighting; load levelling; hybrid-electric vehicles; engine start; uninterrupted power supply (UPS); computer back-up; medical equipment; solar power data processing; electronics; defence; aviation; oil and gas industry; and material handling.

The inherent characteristics of VRLA – AGM technology e.g. low internal resistance, high energy/power density and fast recharge make this technology particularly suited to the Motive Power sector where opportunity charge, fast charge & reduced maintenance/maintenance free characteristics are desired.

VRLA AGM batteries in a nutshell:

- Din & BS footprints
- Superior high rate power density
- Exceptional cycle life
- High stable voltage delivery
- Widest operating temperature range
- High surface area allows TPPL product to reach a high state of charge in fast charging applications
- Flexible mounting and operation orientation (except inverted)
- Classified as “Non-spillable Batteries” for convenient shipping
- Shelf life of more than two times that of conventional lead-acid batteries

3.2 Lithium-based battery technology

Lithium ion (Li-ion) batteries have been commercialised since the beginning of the 1990s and captured 50% of the small mobile phone market in only a few years. Despite this, there are challenges associated with making large-scale Li-ion batteries. Manufacturers are working to reduce the cost of Li-ion technology, and prices are expected to drop further with the expansion of automotive and industrial markets.

A lithium ion battery system is an energy storage system based on electrochemical charge/discharge reactions that occur between a positive electrode (cathode) that contains some lithiated metal oxide and a negative electrode (anode) that is made of carbon material or intercalation compounds. The electrodes are separated by porous polymeric materials which allow for electron and ionic flow between them, and are immersed in an electrolyte that is made up of lithium salts (such as LiPF₆) dissolved in organic liquids.

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.

In practice, the label 'Li-ion' refers to a variety of chemistries, depending on the electrodes cathode. Lithium ion batteries come in a number of different varieties, including:

- different cell shapes: cylindrical, prismatic, pouch
- different electrochemistries, including LiCo₂, LiNCA, Li-NMC, LiFePO₄, LiMn₂O₄, LiT₀, yielding different nominal cell voltages (typically ranging from 2.2V to 3.7V)
- liquid electrolyte or polymeric electrolyte
- different electrode thicknesses depending on the energy/power ratio

Li-ion cells are not usually used directly for industrial applications, but instead as serial and/or parallel assemblies in battery modules or packs to form a complete battery system.

To operate in the recommended voltage, current, temperature limits, and to ensure safe and reliable performance, Li-ion requires electronic monitoring and control. This management system also allows the battery to be "smart" and to communicate with the host application about its state of charge (SOC), state of health (SOH), and other vital data. This is of great benefit to fleet operators, enabling them to schedule their workload proactively.



Of course, Li-ion is known for its low weight (lithium is the lightest metal in the periodic table) and compact size - Li-ion batteries have high energy/power density so they can make optimum use of the sometimes restricted installation footprint available.

A significant advantage of the Li-ion electrochemistry is its capability to accept very high rates of charge (including regenerative braking energy recovery) and discharge. Full charge is achieved in less than one hour with appropriate equipment.

Benefits include less equipment downtime, leading to greater availability. As they are sealed for life, Li-ion batteries are essentially maintenance-free, they do not need topping up with water. Li-ion batteries also offer a long life, both in terms of cycle life and calendar life. So while the initial acquisition costs of a Li-ion battery appear high, the need for reduced maintenance and battery replacement over the operational life of, say a forklift truck, present a strong TCO (Total Cost of Ownership) argument.

3.3 Sodium-based battery technology

A Sodium Nickel chloride cell operates at temperatures between 270 °C and 350°C and each cell has a steel case and a metal-ceramic seal, providing an hermetically sealed cell, maintenance free along life. The cathode is based on nickel (Ni) and common salt (NaCl) while the anode consists of molten sodium (Na). The electrolyte is made up of tetra-chlor-aluminate of sodium (NaAlCl_4), liquid at the operating temperature of the cells and by a ceramic separator conductive only for sodium ions.

Sodium nickel chloride batteries have been commercialised since the 1990s and were originally mainly found in electric vehicles (EVs) and hybrid-electric vehicles (HEVs). Today their use has been broadened to include industrial applications, including telecom and back-up markets and on/off grid stationary energy storage systems for ancillary services to the electrical grid. When used in vehicles, they provide advanced solutions for low emission mobility, with a focus on professional applications such as utility vehicles; electric and hybrid buses; delivery vans; and trucks.

Sodium batteries have also been adopted for use in mining equipment, naval applications and a range of specialist machinery. They offer specific advantages when used in below-ground applications, compared with standard diesel equipment. This can have a significant negative impact on the comfort and health of workers due to diesel particulate matter (DPM) pollution and heat generation, both of which require high levels of ventilation. Such ventilation is very expensive, both in terms of infrastructure and operational costs (energy and maintenance). Battery-powered machines overcome these issues by offering cleaner and quieter operation.

Ambient conditions in environments such as mines are typically very harsh, often characterised by extremes of temperature and humidity. Furthermore, the impact of strong shocks and vibrations can be significant constraints on the performance of machinery. The characteristics of sodium nickel batteries mean that they work well in these hostile environments, and as a result are being increasingly widely used in mines and other below-ground applications.

Sodium batteries are also increasingly commonplace in both hybrid and fully

electric nautical propulsion systems. They are particularly relevant when used on lakes and enclosed bodies of water where standard internal combustion engines are increasingly prohibited.

As demand for energy storage grows, the characteristics of sodium batteries, which are light and offer easy storage for winterisation, will give them key advantages. As described above, they also have an excellent safety profile and zero maintenance requirements.

Key advantages of sodium batteries for mining applications:

- high energy densities permit long run-times on a single charge
- zero emissions
- no maintenance requirements
- intrinsically safe
- can be strengthened against the harsh environment with a rugged stainless steel box and thermal insulation
- high cyclability for long-lasting operation

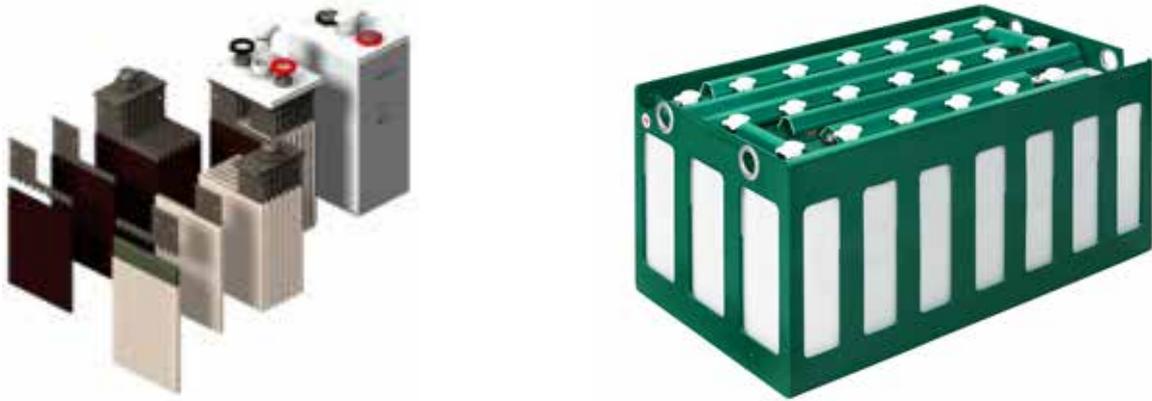
3.4 Nickel-based battery technology

“Nickel” is applied in different alkaline accumulator technologies such as nickel-cadmium, nickel-metal hydride, nickel-hydrogen and nickel-zinc. The application of nickel in accumulators started at the end of the nineteenth century.

Nickel-based batteries are the second most used electrochemical energy storage after Lead-based batteries. They serve special markets where energy must be stored in extreme climate or cycling or fast charging conditions. Different designs are available: pocket, sintered, plastic-bonded, nickel foam, and fiber electrodes. Cells are prismatic or spiral wound cells, flooded (vented) or valve-regulated (maintenance free). Alkaline cells can be connected in series and parallel to build battery systems with the desired voltage, energy and power characteristics.

Nickel-cadmium and nickel-metal hydride are the most applied alkaline industrial battery systems. They have a nominal cell voltage of 1.2 V and are produced with capacities from 0.5 Ah to 2,000 Ah. Their energy efficiency can be above 95% depending on the application.

Alkaline cells are very robust and well suited for operation in critical environments. This robust design of the cells therefore means an absolutely reliable energy storage, even under the most severe operating conditions.



Their design life is 25 years and they can reach more than 3,000 turnovers of their nominal capacity. The lack of sensitivity of the nickel-cadmium batteries to external factors (e.g. low temperatures) excludes the risk of sudden battery failure (“sudden death”). Their operation temperature range is very wide: -40°C to $+60^{\circ}\text{C}$. They can be connected in large strings without need for sophisticated management systems. Collection and recycling of used industrial alkaline batteries is approximate 100% in Europe. The battery industry has set up a closed well controlled loop recycling process. The battery manufacturer takes back used batteries which are then recycled at certificated companies. The recycling products are used in different industries (e.g. steel) and of course are fed back into the manufacturing of NiCd batteries.

Future development will focus on increasing cycle life, extending temperature range and reducing costs. Active materials, collector materials, additive materials, and production methods will be subject of R&D projects. In total, with respect to performance, reliability, operational safety and durability against adverse environmental influences, alkaline batteries cannot be replaced by any other battery technology – today and in future.

Nickel-based batteries in a nutshell:

- Excellent cycling behavior
- High efficiency of above 95% possible
- Excellent performance in extreme temperatures: Well suited for very low and high temperatures
- Use under difficult conditions – very good mechanical and electrochemical stability
- Extremely robust design of the cells means an absolutely reliable energy storage – even under the most severe operating conditions
- Especially suited in motive power applications where operation around the clock is required

3-5 Innovation of Motive Power Battery technologies

Batteries have come a long way over the last century. Thanks to a series of innovations in their chemistry and design, they are now safer and more environmentally friendly than ever, as well as often being maintenance-free. Since their invention, they have been the focus of constant innovation, and this has often triggered breakthroughs both in the industry and society. Two related factors are now having a particularly big influence on the development of batteries. Firstly, regulators are demanding constant improvements in chemical energy storage to meet tighter safety and environmental standards. Secondly, machinery incorporating electrified traction is becoming an increasingly important part of the response to guidelines and regulations governing both health and environmental standards.

Motive power batteries are exploited in very demanding cycling patterns. They experience large power shifts, deep discharges, operation at partial state of charge, fast charging, opportunity charging, highly varying temperatures of operation and mechanical stress related to operation in motion. Motive power users are very sensitive to levels of battery maintenance, which can pose serious disruption to the use of vital equipment. Motive power batteries are on the technological frontier of medium-scale energy storage, and to meet their demanding applications the industry is rapidly adopting new chemistries, as well design changes to existing battery types.

Existing traction batteries can give maintenance-free operation for years and over thousands of charge-discharge cycles. Some limitations that were commonplace until a few years ago have been addressed by adopting new battery chemistries for motive power applications, such as lithium- and sodium-based cells. These offer improved cycle life time, power and energy densities, along with more flexible cycling patterns. At the same time they pose new challenges related to their design, manufacturing, operation, safety and recycling. The established lead-acid technology has known drawbacks, particularly with regard to power density and cyclability. On the other hand, it benefits from decades of evolution and optimisation, with breakthroughs such as VRLA technology, gel electrolytes, and a reduction in the amount of lead used. As a result lead-acid batteries are safer and cheaper, as well as being outstandingly robust. The growing range of battery types available for motive power allows for an increasingly good match between the specifications of the battery, the needs of the particular customer and the policies regulating the manufacturers and users of these products.

In addition to creating innovative products, battery manufacturers have not overlooked opportunities created outside their core field of research and development such as control electronics and information technology. It is more and more common for monitoring systems to be integrated with batteries to provide optimal performance, as well to help increase the productivity of related machinery.

It is noticeable that the division between stationary (backup) and motive (cycled) use of batteries is being blurred with the growing demand for storage of renewable energy as part of the development of smart and semi-detached power grids. As such, harmonised and steady progress in all aspects of battery-based energy storage is growing in importance.



4 Contribution of Electrification of Motive Power to EU Objectives

The European Union (EU) has always been a frontrunner in the promotion and development of renewable energy, steering the effort to combat climate change by encouraging the shift to a low-carbon economy while stimulating economic growth.

That is why the current ‘European 2020 Framework for Renewable Energy’ sets a binding target of 20% of final energy consumption from renewable sources by 2020 between now and 2020¹. Moreover, in the ‘Clean Energy for All Europeans’ package, the European Commission committed to cut CO2 emissions by at least 40% by 2030².

The electrification of motive power through batteries is contributing to the decarbonisation of the European energy mix by enabling electricity generated from renewable energy sources to be efficiently stored. Battery energy storage is an optimum solution for storing energy and facilitates efficient energy use.

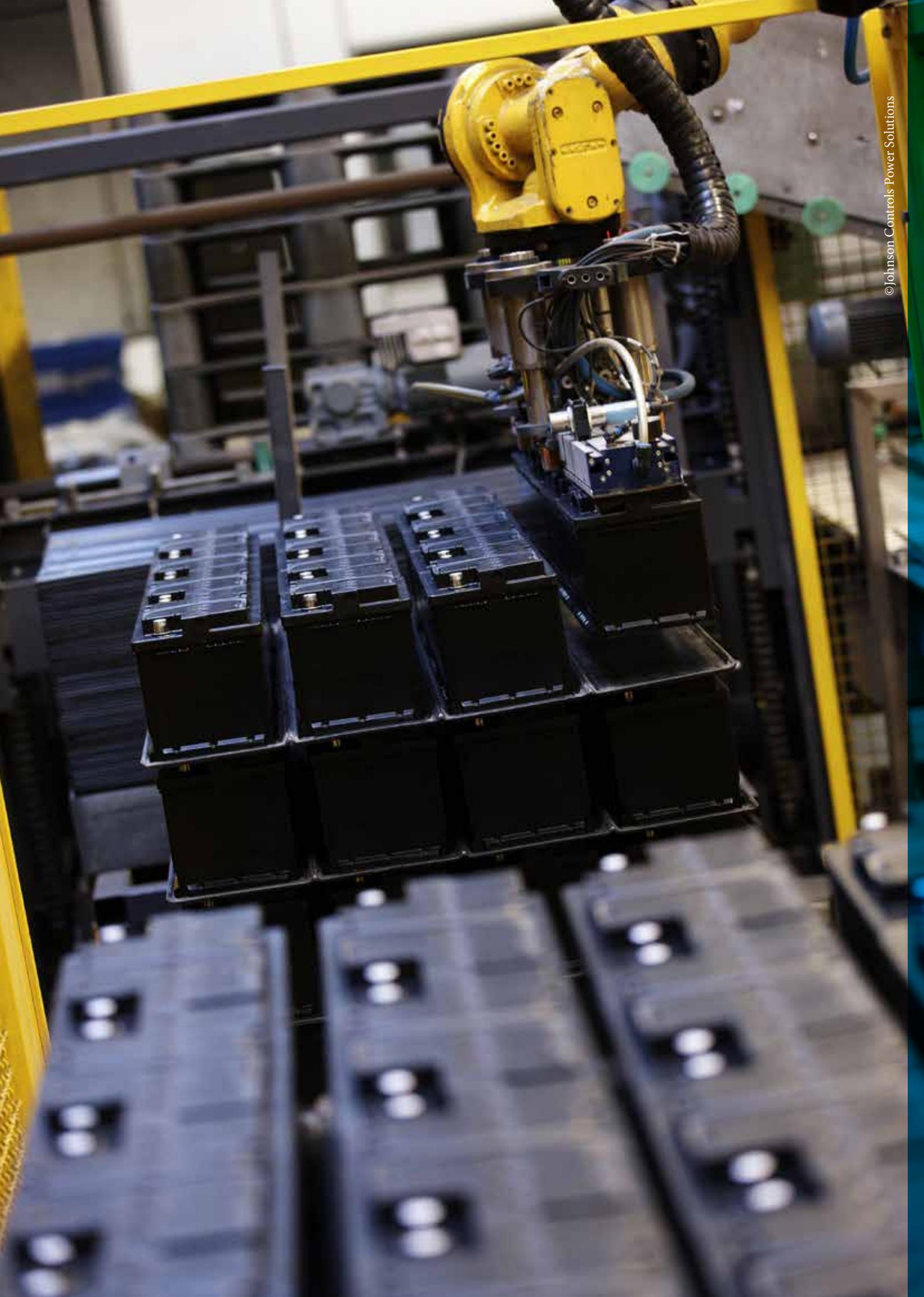
Moreover, by playing a key role in nearly all sectors of industry and the economy – if not directly, then through logistics and material handling applications – the motive power sector can help the European Union to be more competitive and generate growth and jobs.

4.1 Emission Reduction as a driver for electrification

Air quality has improved considerably in recent decades. However, the European Environment Agency (EEA) has identified that the European Union is still far from achieving levels that do not result in unacceptable risks to humans and the environment. The EEA estimates that every year in the EU-28, 72 000 premature deaths are attributable to nitrogen dioxide (NO₂) and 403 000 to particulate matter (PM). According to the European Commission, the health-related costs of air

¹ <https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition>

² http://europa.eu/rapid/press-release_IP-16-4009_en.htm



pollution in the EU are in the range of €330–940 billion per year.

Emissions reduction is one of the main drivers behind electrifying the motive power market. The market for electric industrial vehicles is already large because, of course, indoor use of motive power applications demands electrification.

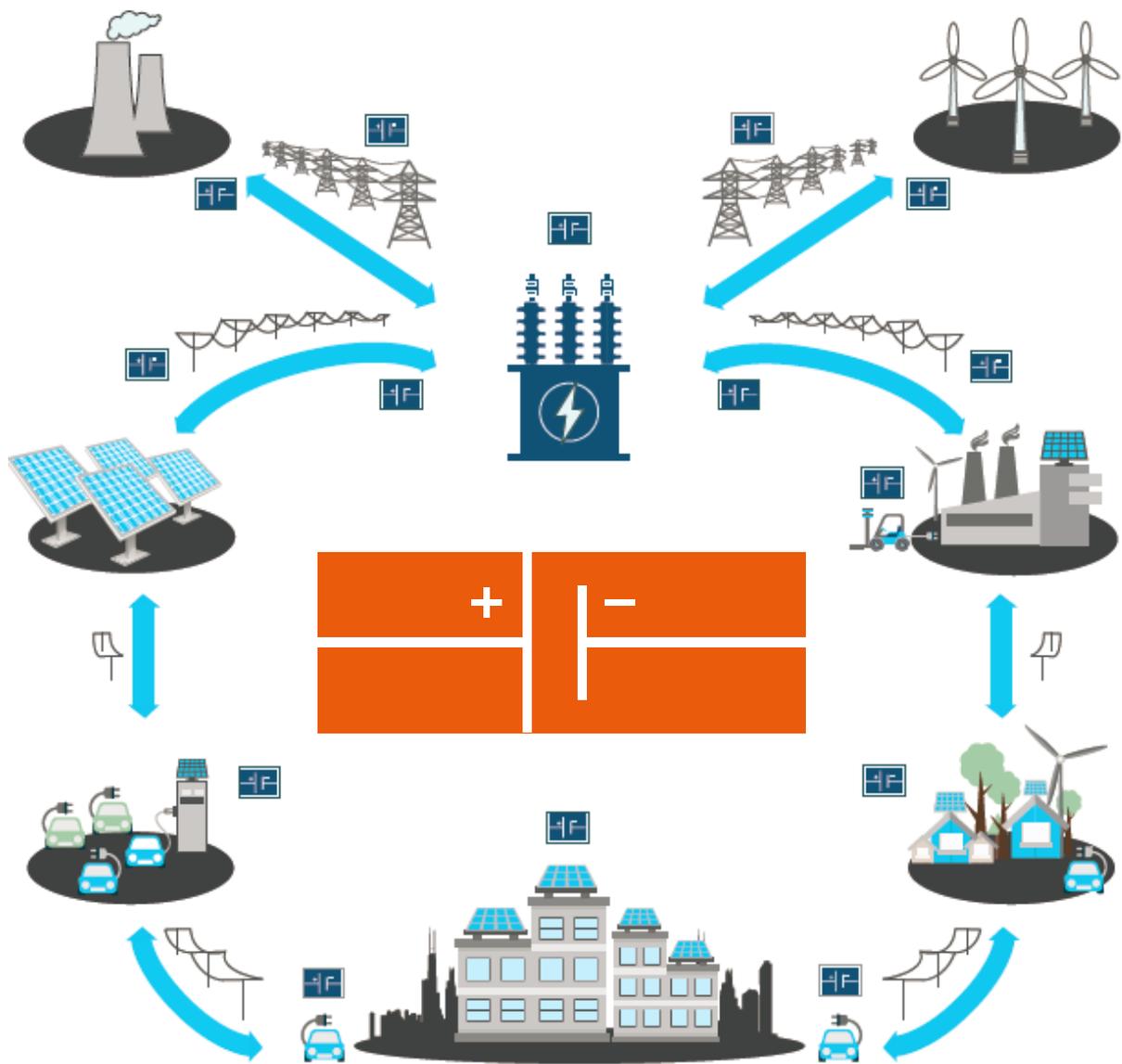
Emissions generated by ‘non-road mobile machinery’ (NRMM) are regulated by a new Regulation³ which came into force on 1 January 2017. The European policy on non-road mobile machinery emissions aims at progressively reducing pollutant emissions, and thus phasing out equipment with the most polluting engines. NRMM includes machinery used in the agricultural sector (for example tractors, harvesters, sprayers and chainsaws), road construction (concrete pavers, cement mixers, bulldozers) and railways, as well as inland waterway vessels (IWVs) such as barges. The NRMM Regulation defines emission limits for NRMM engines based on different power ranges and applications. It also lays down the procedures engine manufacturers have to follow in order to obtain order to obtain type-approval of their engines – which is a prerequisite for placing their engines on the EU market. This is exactly where batteries can step in as an alternative energy source to reduce emissions.

4.2 Motive power batteries as service providers to the electricity grid, either as demand response providers or as active ancillary services providers (through aggregation).

The total capacity of motive power batteries in Europe amounts to more than 20 GWh, way larger than total installed battery energy storage capacity (less than 1 GWh worldwide) or the capacity of deployed electric and hybrid vehicles, which are still quite limited. These batteries are usually charged from the main electricity grid, and as such represent a burden to the electricity system. The charging time varies from 4 to 12 hours, depending on the technology used.

However, motive power batteries have the potential to become a source of flexibility for the electricity system. The concepts of smart charging and vehicle-to-grid – usually applied to electric cars and vans – can also be relevant for motive power batteries, which compared with on-road vehicles have the advantage of existing wide deployment, with a correspondingly large capacity.

³ Non-Road mobile machinery emissions – European Commission https://ec.europa.eu/growth/sectors/automotive/environment-protection/non-road-mobile-machinery_nl



Location of Batteries in the Electricity System

Large numbers of motive power batteries can be aggregated to change their charging time according to fluctuating electricity prices, reducing the burden on the grid. Indeed, in vehicle-to-grid mode batteries could also inject power into the grid and provide several ancillary services, including:

- valley filling (charging at night when demand is low)
- peak shaving (sending power back to the grid when demand is high)
- buffer storing (buffering renewable energy generated by stochastic sources as solar and wind power)
- regulation services (keeping voltage and frequency stable)
- providing spinning reserves (meeting sudden demands for power)

To be able to provide these services, some regulatory barriers should be addressed by the European Commission's proposed clean energy package⁴. For instance, a proper definition of energy storage as a separate asset category of the electricity system should be proposed to solve the issue of double grid fees (paying network fees both for charging and discharging). Indeed, a proper framework for aggregators should be developed to clarify their rights, duties and requirements.

4.3 Noise Reduction as a driver for electrification

Noise is identified by the European Commission as a “one of the most pressing problems” in urban areas⁵. That is why Directive 2000/14/EC aims to harmonise EU Member States policy on noise emission limits of construction and other equipment used outdoors. The Directive not only removes technical barriers to trade and but it also controls noise emissions into the environment.

The electrification of motive power applications using batteries can ensure that equipment meets the noise limits that are set out. A battery-driven application does not produce exhaust or engine noise, significantly reducing noise output, since the engine is the dominant source of noise for most construction equipment (Wilson, Ihrig & Associates, 2014⁶).



⁴ <http://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition>

⁵ <http://ec.europa.eu/growth/sectors/mechanical-engineering/noise-emissions>

⁶ Caltrain Peninsula Corridor Electrification Project Noise and Vibration Technical Report, February 2014, Wilson, Ihrig & Associates, <http://www.caltrain.com/Assets/Caltrain+Modernization+Program/DEIR/Appendix+C+Noise+Study.pdf>

4.4 Circular Economy: recycling of Motive Power Batteries

1. Lead-based batteries:

The recycling of Motive Power batteries follows the already mature process set up for automotive batteries. The collection and recycling of batteries is an efficient and cost effective process that operates in a well-established infrastructure. Within the EU, close to 100% of lead-based batteries are collected by specialised companies and recycled within specialized recycling facilities (secondary lead smelters) in a closed loop system operating under strict environmental regulations. From an end-of-life perspective, this process dramatically reduces the need for production of additional virgin materials such as primary lead and plastics – the most important cause of environmental impact in the cycle life of the product⁷.

2. Lithium-based batteries:

Li-ion batteries can be recycled either by pyrometallurgy or/and by hydrometallurgy. A closed-loop recycling process, with high installed capacity has been developed. End-of-life cells and modules, as well as production scraps are not crushed, they are directly treated. From these batteries, valuable metals are recovered so that they can be converted into active cathode materials for the production of new rechargeable batteries.

Large industrial or EV/HEV Li-ion battery systems are first discharged, then dismantled and recycled according to the following fractions: Modules/cells, Electronics and PCBs, Outer casing and cables.

Li-ion batteries contain only a small fraction of lithium (<2% w/w). Intrinsic value for the Li-ion recycling business currently comes from the valuable metals that are more highly priced than lithium. Recycled lithium is as much as five times the cost of lithium produced from the least costly brine based process. Though lithium is recyclable, currently, it is not competitive for recycling companies to extract lithium from slag and almost none of the lithium used today in Li-ion batteries is completely recovered and separated from the slag. However, the lithium content of the inert slag gives specific properties to this slag mainly used for quick setting cement.

3. Sodium-based batteries:

Recycling is no issue for sodium nickel chloride batteries. The basic materials of a sodium nickel chloride cell are nickel, iron, common salt and ceramic. The cell case and the battery box are made of steel and thermal insulation is provided by a silica-based material. All common materials are unaffected by possible shortages and are easily recyclable. An exhausted battery is recycled in steel production; the metallic boxes, the nickel and the iron content become part of the final product, and the salt and ceramic will form the slag in a process-consistent way, with the slag normally used by construction industry. The recycling process is set up and available at industrial level. A possible improvement could be to earn value from thermal insulation material through secondary uses.

⁷ EUROBAT, ILA, ACEA, JAMA and KEMA, A review of battery technologies for Automotive Applications for Automotive Applications, (2014)

4. Nickel-based batteries:

As part of the requirements of the batteries directive (2006/66/EC), an Extended Producer Responsibility regime has been set up for spent industrial batteries, whereby Producers must take back and recycle such spent products free of charge. This category of products includes, inter alia, industrial Ni-Cd batteries.

Partnerships between Producers, logistical companies specializing in the transportation of hazardous waste, and fully permitted recyclers ensure that industrial end users can easily dispose of their spent industrial Ni-Cd batteries in a way which ensures proper recycling of the used accumulator, the reuse of their components to manufacture new batteries or other industrial goods, whilst protecting the environment from the hazards of improper waste treatment.

The recycling process is conducted at the facility of fully permitted recyclers. There are four Ni-Cd battery recyclers in Europe able to receive and process used Ni-Cd batteries collected. The recycling involves the safe extraction (by means of a distillation process) of the cadmium, which is then reused to make new battery electrodes. The ferro-nickel residue is then segregated to be used as an additive to manufacture stainless steel. These metal fraction can be reused indefinitely as their characteristics are not degraded in the recycling process. Moreover, some facilities use the alkali electrolyte as a reactant to neutralize and precipitate acidic waste, and reuse plastic fractions for new plastic and/or ensure they are incinerated with energy recovery.





4.5 Innovation

The European Union's Innovation Union strategy aims to create an innovation-friendly environment. Innovation plays a key role for the European Union to be competitive in the global economy.

All types of motive power batteries have been constantly improved over time, and innovations will continue to be introduced. Batteries have always been used to provide traction power. The construction of the first electric motors and rechargeable lead acid batteries both date from the 1800s. Since then the two technologies have been closely linked to provide what is now known as motive power. In this field, progress in energy storage goes hand-in-hand with the design of new machinery, leading to higher productivity at lower human and environmental cost.

The innovation process observed in the development of motive power batteries has not happened in isolation. Rather, it is an important part of a broader change of thinking about energy in modern societies. Battery technology has a lot to offer with regard to improving both sustainability and quality of life. Motive power has an important role to play, since it is present in nearly all sectors of industry and the economy, either directly or through material handling applications that are central to logistics.



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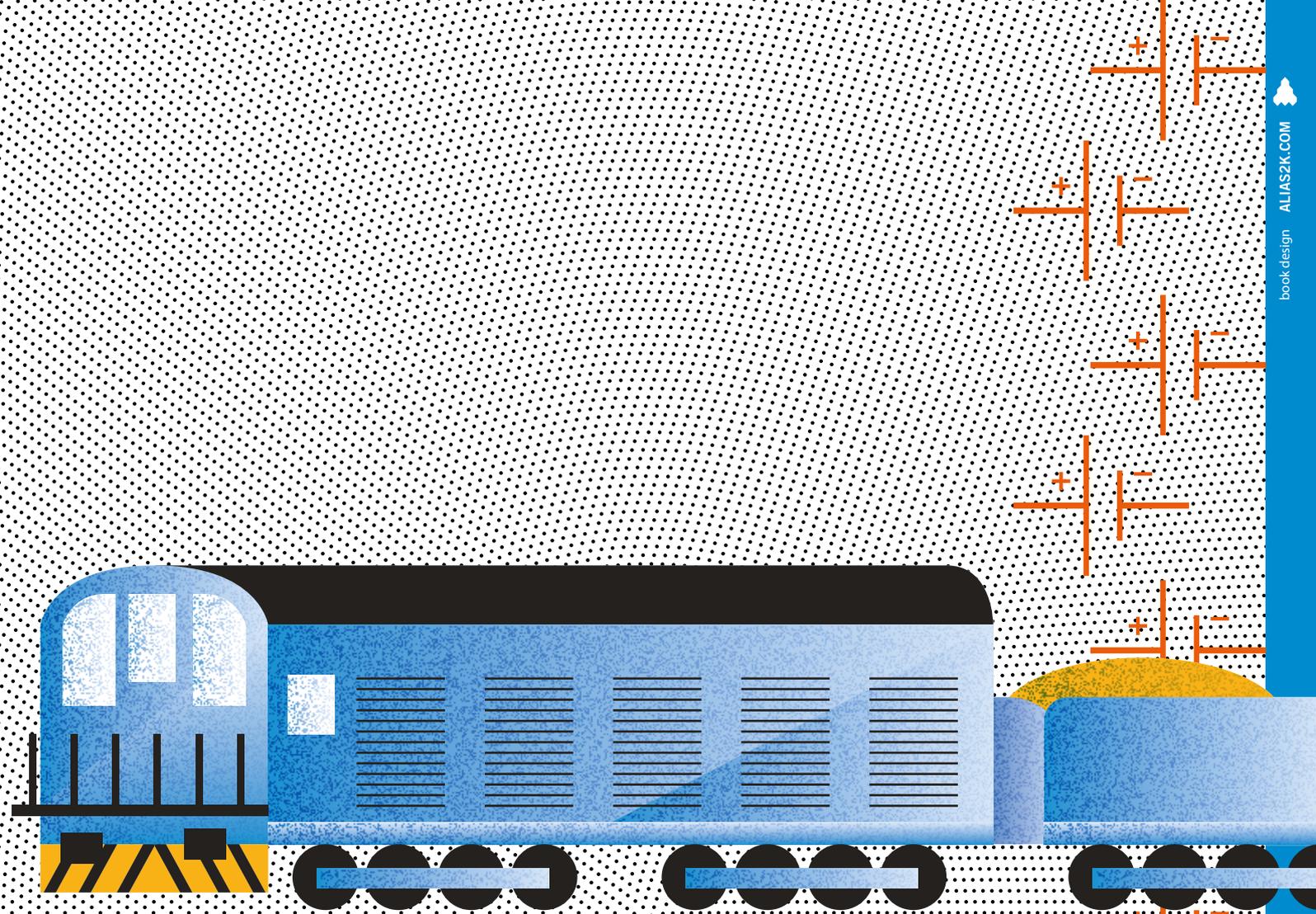
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The great variety of motive power applications are covered by different battery technologies, which all have their own specifications to ensure all the specific needs of applications are covered. All types of motive power batteries have been constantly improved over time, and innovations will continue to be introduced, so that indeed they can continue to contribute to EU objectives.

**MOTIVE
POWER
BATTERIES**
BATTERY TECHNOLOGY FOR
MOTIVE OFF-ROAD APPLICATIONS

