MARKET INTELLIGENCE REPORT

COBRA

KEY TECHNICAL, POLICY AND MARKET DEVELOPMENTS INFLUENCING THE ELECTRIC VEHICLE BATTERY LANDSCAPE

CURATED BY
LUKAS MARTHALER
PIOTR GRUDZIEN
MAARTEN BUYSSE
MARCOS IERIDES &
AMY MCCREADY
BAX & COMPANY
VALUE FROM SCIENCE AND TECHNOLOGY

REVERSE LOGISTICS

MARCH 2022 EDITION

INTRODUCTION

Li-ion batteries have gained a prominent position in the ongoing electrification of global transport. To counter a range of their negative externalities, retaining critical materials from Li-ion batteries could be crucial **[1]**. Examples of retaining material value include battery reuse, remanufacturing, repurposing, and recycling. To support the value retention of Li-ion batteries, a safe and efficient reverse logistics chain is needed. Although currently only several hundreds of batteries are reaching the end of their first life, in the next decade the number of returned electric vehicle batteries (EVBs) is expected to surge. By 2030 there will be 111,000 tonnes (or 25 GWh) of end-of-life EVBs in Europe, while almost 500 GWh of new batteries will be placed on the market **[2]**. This means tens of thousands of heavy-duty trucks transporting EoL batteries a year, many of which transport them as dangerous goods.

With the EU's focus on establishing the safest and most sustainable value chain for Li-ion batteries in the world, the surge in EV sales and society's growing concern for sustainability, the interest in reverse logistics of Li-ion batteries is increasing. Public and private stakeholders are urged to create new regulations, business models and supporting technology.

This market intelligence report will dive into our current understanding of reverse logistics, the forms it might take in the future, its challenges, and enablers.

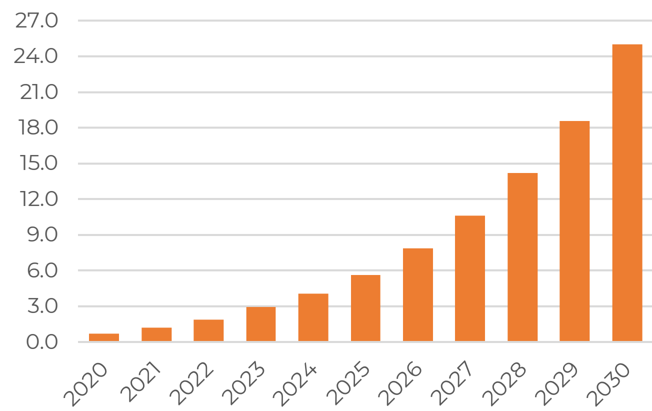

Figure 1. EVBs reaching end-of-life in Europe (GWh) (Source: Circular Energy Storage)

DEVELOPED BY


Lukas Marthaler
Junior Innovation Consultant
l.marthaler@baxcompany.com


Piotr Grudzien
Innovation Consultant
p.grudzien@baxcompany.com


Maarten Buysse
Innovation Consultant
m.buysse@baxcompany.com

Bax & Company
cobra@baxcompany.com
Phone: +34 93 476 04 44
www.baxcompany.com


Marcos Ierides
Senior Innovation Consultant
m.ierides@baxcompany.com


Amy McCready
Communications & PR Officer
a.mccready@baxcompany.com

OVERVIEW

WHAT IS REVERSE LOGISTICS IN THE CONTEXT OF EVBS?

Reverse logistics, a term coined in the 1990s, now firmly embedded in logistics can be defined as: "the process by means of which goods are transferred from their final destination to the point of origin with the aim of recovering value or of reducing waste" **[3]**. Reverse logistics in the context of EVBs start when the EV user decides that the battery is not satisfying the need and stop when the battery reaches the point where the remaining value is utilised, e.g., through recycling, repurposing or remanufacturing.

Figure 2. Reverse logistics process

EVB REVERSE LOGISTICS STEP BY STEP

To pinpoint specific challenges of battery reverse logistics let's have a closer look at each part of the process.

STEP 1: COLLECTION AT THE END OF 1ST LIFE

When the EV owner decides to replace the battery, the vehicle must be **delivered** to an authorised facility, usually a car dealership, dismantler, or workshop. This can be done either by the owner (if the vehicle is functional) or insurance company if the vehicle was subject to a car accident. In either case, if the battery casing remains undamaged, the chassis of the car is assumed to provide enough protection for transportation purposes.

STEP 2: EXTRACTION AND ASSESSMENT

Once at the authorised facility, the battery is **extracted** from the vehicle and its state is **evaluated**. The authorised facility should have the equipment and know-how required to assess the state of health (SoH) and state of safety (SoS) of the battery. Based on this information a decision is made whether the battery can be:

- Repaired and used in the same vehicle;
- Sent to remanufacturer which prepares the battery for the second use in EV;
- Sent to repurposer which adapts it e.g., for stationary storage;
- Sent to recycler if the battery can no longer be used in other applications.

STEP 3: PACKAGING AND STORAGE/ TRANSPORT

Regardless of the battery state, after extraction from EV the battery is usually properly **packaged** (depending on its state of safety) and **stored** at the extractor facility until the further step is taken. In the meantime, the car gets a new battery delivered by the OEM or a 2nd life battery. Once a higher number of old EVBs is reached at the extractor, a logistics company collects and **transports** the batteries to the receiving facility (remanufacturer, repurposer or recycler).

STEP 4: PRE-TREATMENT

Before the battery can be remanufactured, repurposed, or recycled, a series of pre-treatment activities must be performed. If it has not been already done at the extractor, the battery is **discharged** in this step to increase its safety. Then, the battery is **disassembled/dismantled**. The level of disassembly depends on the further application. In case of repurposing and remanufacturing, battery packs are dismantled to replace faulty modules or cells and adapt the electronics. In case of recycling, batteries are dismantled to separate their components which require different treatment processes.

STEP 5: RECLAIMING VALUE

The further activities performed by recyclers partly lie within the scope of the previous Market Intelligence Report [1], while remanufacturing and repurposing will be covered in one of the next reports.

STAKEHOLDERS INVOLVED

Since the reverse logistics industry is not yet established, each activity explained above can be performed by more than one stakeholder type (see Figure 3). At the same time, no player in the EU would be able to vertically integrate all the reverse logistics processes. It is expected that once more batteries reach their EoL, the industry will consolidate and specialise, e.g., creating a network of authorised workshops with expertise in handling EVBs and dedicated pre-treatment plants.

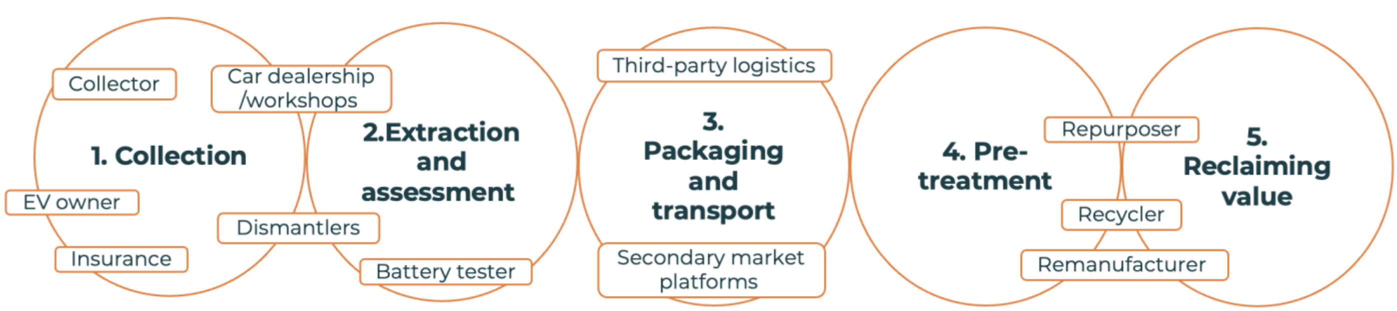

Figure 3. Stakeholders per RL step

RETURN BATTERY FLOWS

In the first scenario, an EVB reaches the end of its first life due to car accidents, manufacturing defects and other faults. Since the first mass-produced EVs appeared in 2013-2014, these batteries are in most cases still **on warranty**, which on average lasts 8 years. In such a scenario, the OEM replaces the default battery through an authorised dealership and often takes it back to use in R&D second life projects. According to the data coming from OEMs, **only 2%** of all batteries are returned when under warranty **[4]**.

The second scenario occurs when the EV is **after warranty** period and the user decides to **replace it** because of an accident (**6%**) or insufficient performance due to natural degradation (**2%**). In this case, the car owner must pay for the repair, buy a new battery or a used one, while the old battery is often repurposed.

In the third and most common **scenario** (**90%**), the battery reaches its end of life because the EV is simply **not economical to repair** and the owner decides to **sell it** to another user or to the dismantler, which offers EV parts on a third-party market. The dismantler decides on the next application for the battery, based on its remaining value. If the battery does not have any useful life, it is sent to recycling.

In future, the percentages presented above may change in favour of the first scenario. Once higher quantities of EVBs reach their end of first life, the **car OEMs are expected to lead the reverse logistics process** by offering take-back deals to end-users, based on the live data coming from the vehicles. This way, manufacturers will be able to maximise the value of the EVBs, providing them with a second life in collaboration with repurposing partners. Another possibility is that the third-party market for EVBs will grow and facilitate reverse logistics instead of the OEMs. Both developments will help reduce the environmental footprint of EVBs.

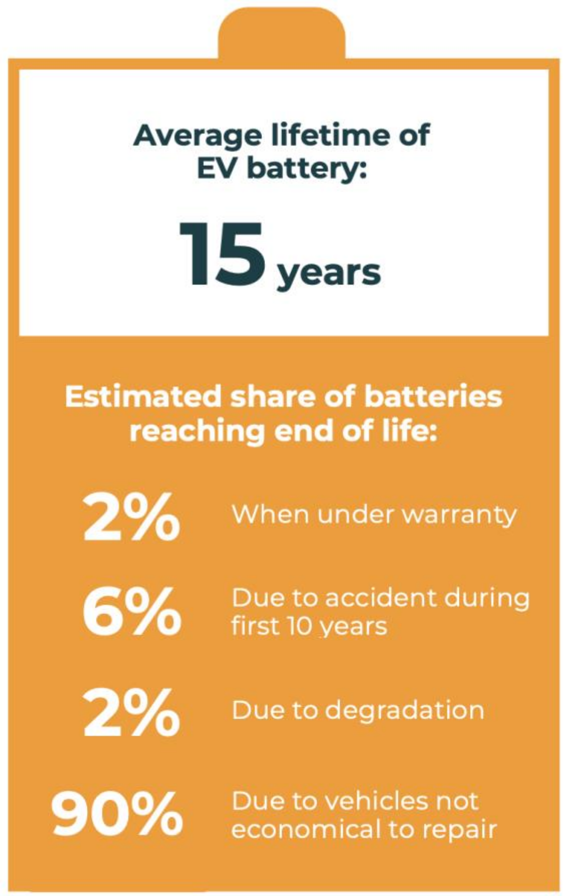

Figure 4. Return battery flows ***[4]***

CHALLENGES FOR REVERSE LOGISTICS IN THE EU

The treatment market of used EV Li-ion batteries and their reverse logistics is still very immature [5]. While reverse logistics and subsequent treatment are separate stages, they share several challenges. Challenges can be categorised as: market and social, regulatory and governance, technology gaps.

MARKET & SOCIAL

According to [6] market and social challenges are currently the largest to the establishment of Li-ion battery RL. There seems to be a **lack of incentives and enablers** for the industry.

LOW REGULATORY PRESSURE AND ECONOMIC INCENTIVE TO CHANGE

Currently, a lack of proper regulation stems from a lack of community pressure. Several researchers point to citizens' lack of awareness of RL urgency and competitive advantage to the European EVB industry as a regulatory and social barrier [6]. Economic incentives are lacking as well. Many companies seemingly follow a wait-and-see strategy, planning their End-of-Life (EoL) capacity parallel to the battery returns growth [7]. Moreover, the combination of lowering costs for new batteries and high costs of reclaiming battery value deters investment. This stems from decreased virgin battery costs, and the high handling and transport cost of Li-ion batteries. For example, transportation of EoL EVBs alone accounts for roughly 40% of the recycling cost [9]. Moreover, the low economies of scale prohibit significant cost reductions per unit.

DISPERSED & UNSTANDARDISED SUPPLY

There is a lack of a consolidated supply of standardised batteries returned from EVs. Sourcing proves to be troublesome for remanufacturers and recyclers, that now must rely on direct communications with OEMs or independent collectors/ dismantlers/extractors. Consolidation is thus still lacking on a large scale and proves to be a market challenge for achieving economies of scale [5].

REGULATORY & GOVERNANCE

The infantile market maturity of Li-ion battery RL also shows in the low level of standardisation and regulation with regards to testing, labelling, transportation, and collection responsibilities.

NO EU-WIDE LABELLING SYSTEM

While a wide variety of EVBs exists, there is a lack of proper labelling and registration systems, making dismantling and sorting activities more difficult. EVBs differ much in their materials, electrochemical characteristics, geometries, usage and treatment (e.g., refurbishment) history. Because of no clear labelling and registration system in place, dismantlers and recyclers have started working together with specific OEMs [5]. Of course, this could prove to hamper free market mechanisms and efficient treatment of higher volumes of Li-ion batteries in the future.

WASTE SHIPMENT PROCEDURES ARE BURDENSOME

Another complicating factor is the shipment of battery waste, which is considered a hazardous good. In the recent proposal *Directive on Waste Shipment*, the European Commission has recognised the procedural burden of intra-EU transport of waste, which often leads to delays and therefore extra transport costs. For example, when transporting hazardous waste (e.g., battery waste) through the EU, every encountered member state must be notified and give consent to the transporter [10], [11].

EXTENDED PRODUCER RESPONSIBILITY: UNCLEAR DEFINITON AND TRANSFER

Lastly, under the 2006 directive it has been unclear what the Extended Producer Responsibility (EPR) is regarding Li-ion batteries. Under the *old* directive, Li-ion batteries were not specifically mentioned, as it focused primarily on lead-acid traction batteries and consumer batteries. With regards to repurposing into secondary applications, existing legislation does not define how the EPR could be transferred either. Here, it is important to first define what waste is and when the repurposer (e.g., for stationary energy storage) takes over responsibility for the collection of the waste stream [12].

The main challenges of EVB reverse logistics lie in the **extremely fragmented nature of the market**. All relevant players have hugely varying budgets, capacity, and risk appetites. This is important as the **battery data necessary for purchase often is concealed, unavailable or difficult to establish**, while the **transfer of liability is vague**.

More generally, we are operating in an environment where **the values and incentives are nascent and very dynamic**. There is no consensus established on recycling vs 2nd life usage and all players are moving and trying to find their position. We help accelerate the industry by a) changing the perception of waste and b) ensuring subsequent circular energy storage. This is what will determine whether the EV revolution will be sustainable.

The sector is moving at breakneck speed so keeping up with the pace of change means significant costs: whether in battery design, diagnostics, transport, or second life applications (to name just a small selection) and ensuring proof of concept goes to execution at scale. The different regulatory frameworks on reverse logistics in Asia, the US, and Europe all have nuances and competitive dynamics. **Establishing the State of Safety**, necessary prior to shipping, **requires time and expensive testing processes, which also drives up the costs**.

William Bergh, Founder of Cling Systems
Start-up developing battery trading platform

TECHNOLOGY GAPS

Technology gaps are limiting the safety, efficiency, and scalability of reverse logistics processes, mainly battery testing and disassembly.

LOW SCALABILITY OF BATTERY TESTING

Before EVB repurposing or recycling, the receiving facility should perform tests to estimate the battery state. Several performance metrics include Remaining Useful Life (RUL), State of Health (SOH) and State of Safety (SOS). However, battery state estimation is currently performed per individual cell or module instead of the entire pack, creating a problem in scalability as the number of cells per EVB is growing [5]. Moreover, SOS assessment requires many steps (8 tests as prescribed in UN38.3 standard [12]), many of which are performed with visual inspections, temperature, and voltage measurements. Even having completed these checks, it is hard to get a good grip on the potential problems inside of a battery cell. A well-known example is dendrite growth, which is not visible without opening the battery cell. Only after developing a transparent battery cell, researchers were able to observe dendrite growth within a functional battery (see figure 1) [13]. New automation technologies and modelling are sought to overcome this challenge.

TIME-CONSUMING DISASSEMBLY PROCESS

The EoL batteries which are to be recycled using the hydrometallurgical process must be first discharged to 0% SoC to increase safety during mechanical pre-treatment. The discharging process of EVBs usually involves connecting them to resistors where the energy is dissipated as heat, or to electronic load with an AC/DC inverter so that the energy from the battery can be recovered for further use [14]. Although energy recovery can increase the profitability and sustainability of reverse logistics, it is currently technically challenging. The dismantler/recycler must request the OEM to decode access to the BMS (battery management system) to diagnose and unlock the high voltage port [15]. Developments in EoL battery discharging are thus needed to improve the efficiency of reverse logistics. Lastly, the disassembly of Li-ion batteries remains labour-intensive due to the variety of battery designs, flexible components (e.g., cables), and the electrical and chemical dangers involved [16], [17].

SOLUTIONS FOR REVERSE LOGISTICS

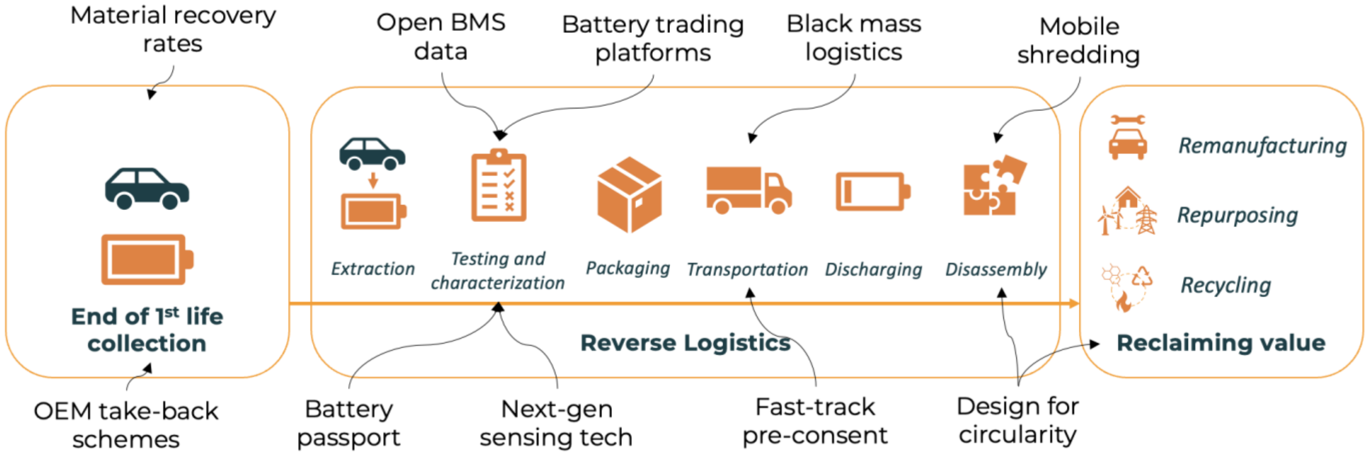

Figure 5. Solutions for Li-ion battery reverse logistics

MARKET & SOCIAL: SPECIALISED STARTUPS & JOINT VENTURE SYNERGIES

SPECIALISED STARTUPS

Start-ups are tackling specific issues within the RL ecosystem. Two such issues include the dispersed battery recovery market and hazardous battery transport. To tackle the dispersed recovery market, platform start-ups consolidate and address the variety of second life battery types. They offer a platform for buyers and sellers of EoL batteries, as well as the registration of batteries and their performance data (e.g., via IoT). Start-ups also address the difficulties related to EoL battery transport by shredding batteries and transporting the resulting recyclate, the black mass. Since transporting black mass is not hazardous, transport hurdles are avoided. Activities include bringing shredding operations to the collection point (e.g., car dismantler) or installing a distributed network of smaller shredding operations.

NOVEL AUTOMOTIVE REVERSE LOGISTICS SCHEMES

Supporting the value retention of EVBs, several OEMs have started testing several reverse logistics models, with Renault and Nissan reaping the advantage of their early EV releases. The first Li-ion batteries from the Nissan Leaf and Renault Zoe are reaching EoL. Thus, they can test different take back schemes ahead of other OEMs. For example, Nissan has launched a take-back scheme in 2018, which allowed car owners to replace their EVBs with remanufactured Renault batteries [18].

REGULATORY: MORE INCENTIVES, EFFICIENCY AND TRANSPARENCY

INCENTIVES FOR MEMBER STATES AND INDUSTRY

The Battery Directive proposal published by the European Commission in December 2020 includes addresses several issues related to Li-ion battery RL issues. The proposal introduces targets for the recovery rate and recycling efficiency of end-of-life EV Li-ion batteries. Alongside these targets, an Extended Producer Responsibility is proposed for manufacturers of Li-ion. Hereby, industry could be incentivised to support the establishment of effective and efficient Li-ion battery recycling streams [19].

FREE INFORMATION FLOW BETWEEN BMS AND BUYER

The proposal also requires OEMs to provide valuable historical BMS data to the purchaser of the battery. While collectors, extractors and dismantlers currently rely mostly on agreements with OEMs for this data, this measure would allow for easier access to usage data, and potentially enable more organisations to be involved in the field of recycling and second use.

NEW WASTE SHIPMENT & ELV REGULATION PROPOSALS

The new Waste Shipment Regulation proposal intends to provide faster and clearer procedures for battery transport.

Firstly, while consent procedures are currently paper-based, the European Commission intends to digitalise them [20]. Secondly, the rules regarding pre-consent facilities are made clearer and faster. Waste treatment facilities can currently receive pre-consent status at the member-state level, which allows for faster and easier shipment procedures. The new proposal intends to harmonise this procedure EU-wide and additionally introduce a fast-track procedure to obtain pre-consent status [20].

Within the next few years, the number of EoL batteries from e-mobility and stationary applications will surge, completely transforming the recycling value chain. This means that both the number and capacity of recycling facilities need to increase. The **new capacities need to be automated to reduce costs and reduce safety risks** in all parts of the value chain.

The **Batt4EU Partnership** under the Horizon Europe research programme focuses both on tackling these short-term challenges and researching long-term solutions like design for sustainable recycling and advanced sorting methods that will enable the direct recycling of components.

Philippe Jacques, Secretary General of BEPA
The Batteries European Partnership Association

TECHNOLOGY: BATTERY TESTING, PASSPORT AND ECODESIGN

IMPROVED BATTERY ESTIMATION TECHNOLOGIES & METHODOLOGIES

A new generation of estimation technologies and methodologies are on their way, with the exploration of six main research directions [21]:

- estimating several battery states categories jointly (e.g., State of Health, State of Charge)
- scaling state estimation from cell to pack level
- advancing sensing technologies
- smart data techniques (e.g., artificial intelligence, machine learning) to estimate battery states
- enhancing estimation algorithms
- electro-thermal-aging management

Accurate and fast battery state estimation is useful across applications (e.g., charging facilities, battery management systems), which could further incentivise sensing technologies and methodologies.

LABELLING, PASSPORT AND DIGITAL TWINS

Featured in the new battery directive and first proposed by the Global Battery Alliance, the battery passport initiative could form the future of battery registration. The Global Battery Alliance is working on this together with industrial partners such as Audi, BMW and Umicore [22]. Several other battery passport initiatives have surfaced as well [23]–[25]. A battery passport could bring transparency, benchmark framework and tracking opportunities for recycling[26]. Here, the quality seal imposed by the passport could be an enabler for the liability issues of repurposing.

DESIGN FOR CIRCULARITY

Lastly, several battery OEMs are implementing design for circularity principles in the development of EVBs. The design for disassembly and standardisation of EVBs bring advantages for all treatment processes. It creates more alternatives for treatment in reverse logistics and a chance to delay battery recycling flows by refurbishing/repairing batteries [27]. However, in the design for disassembly, there remains a trade-off between accessibility, safety, and weight [28].

TECHNICAL DEVELOPMENTS

UK AND HONG KONG RESEARCHERS DEVELOPED A MACHINE LEARNING BASED BATTERY TESTING

To determine the course of action on a returned Li-ion battery, the battery's state needs to be assessed. However, a lack of data on battery degradation trajectory is currently prohibiting relevant modelling approaches to battery assessment. This research applied a machine learning approach using industrial field data to learn how battery capacity degrades over time. This is useful for several battery applications. To reverse logistics, models that can predict the State of Health of EV Li-ion battery is especially useful.

READ MORE

SAFE CONTAINER FOR TRANSPORTATION OF DAMAGED EVBS

Swiss company Thielmann developed a packaging solution allowing for safe long-distance transport of batteries from damaged EVs. The product branded as "Battery Safe Box" meets the requirements set by the dangerous goods directive. The packaging is filled with expanded granulated glass which absorbs heat, while a gas management system safely releases combustion products outside of the box. The packaging can be reused by refilling it with new glass granulate, decreasing the transportation costs.

READ MORE

OAK RIDGE NATIONAL LABORATORY DEMONSTRATES A SAFE AND FAST ROBOTIC DISASSEMBLY SYSTEM FOR EVBS

Researchers from Oak Ridge National Laboratory (U.S., Tennessee) presented an automatic arm that can remove bolts and other housing of EVBs regardless of the remaining state of charge (SoC). While human operators would have to discharge completely the battery, the machine can skip this step, reducing the risk and time needed to extract the battery pack e.g., to the recycling line. The researchers claim their automated system can process batteries 10 times faster when compared to manual disassembly.

READ MORE

US-BASED START-UP REDIVIVUS PREPARES A TRUCK SHREDDING LI-ION BATTERIES ON-SITE

'Redi-Shred', a new solution developed by a start-up from the US, is a mobile recycling system. It consists of a truck that shreds and neutralises Li-ion batteries on-site, turning them into a black mass which can be safely transported to the recycling facility without additional costs related to hazardous materials transport. Redivivus plans to combine this mobile shredding solution with its hydroelectric refining process to commercially recover materials from Li-ion batteries.

READ MORE

MARKET DEVELOPMENTS

SECOND ROUND OF SEED FUNDING FOR A BATTERY DIGITAL TWIN START-UP

A German-based start-up Circunomics develops a solution that will give a unique identity to each battery, digitalising its lifecycle with data regarding performance, materials, and sustainability. The digital twin will help to select the best future use case for each battery, simplifying testing and trading activities. In 2021 the start-up closed the second seed round of €1.8 million, partnering with multinational recycler TES-AMM among others.

READ MORE

A NORDIC START-UP AIMS TO ENABLE MORE EFFICIENT REVERSE LOGISTICS OF BATTERIES

Cling Systems is a start-up building a battery marketplace aimed at car assemblers in the Nordic region and remanufacturers across Europe. The platform will allow matching supply and demand for used batteries, decreasing the costs of reverse logistics. The start-up secured a seed funding of SEK 21 million (USD 2.3 million) coming from 3 venture capitals and 5 business angels.

READ MORE

BATTERY REPAIRS REQUIRE A LARGE NETWORK OF QUALIFIED CENTRES – LESSON FROM OEM

The volume of battery return flows highly depends on the ability of car service stations to perform activities like testing, dismantling and repairs. VW has two qualification centres in Germany, in Erfurt and Wolfsburg, soon to be joined by a third location, in Nurtingen. Employees of the service stations are trained to become high-voltage experts and to be able to repair faulty batteries. VW currently already has 265 such stations with authorised personnel in Germany and aims to increase this number to 450.

READ MORE

LI-CYCLE IS TESTING TWO-STEP *SPOKE* BATTERY REVERSE LOGISTICS MODEL IN THE US

Transporting hazardous waste across states or countries is an expensive business, therefore Li-Cycle, a Canadian-based start-up, developed a battery return model which involves an additional step before the Li-ion batteries end up at the recycling facility. First, batteries are collected and transported to regional *spoke* facilities, where the batteries are shredded and transformed into a black mass, which is then transported as a non-hazardous waste to the hydrometallurgical plant. Li-Cycle currently operates two spoke plants and two others planned. Their first hub plant is expected to begin operation in 2023.

READ MORE

POLICY DEVELOPMENTS

THE NEW BATTERY DIRECTIVE – ENABLER OF 2ND LIFE BUSINESSES

Among many new environmental rules introduced by the new Battery Directive proposed in 2020, some may help create a market for 2nd life applications of EVBs. The document suggests mandatory requirements on labelling and information, a kind of battery passport that would store information on sustainability and data on the state of health and expected lifetime. Furthermore, clear rules of end-of-life management will be established, such as collection targets and a framework for battery repurposing.

READ MORE

EUROPEAN NGOS AND COMPANIES HASTEN EU MINISTERS TO IMPLEMENT BATTERY LAW

While the new Battery Directive has been praised for ambitious environmental targets, it is still being discussed by the EU Member States. The EU Council have recently proposed delays for the introduction of rules targeting the reduction of batteries' carbon footprint and for the phase-in of mandatory supply chain checks for environmental and human rights abuses. 8 battery businesses and 40 environmental NGOs in a letter to EU Environment Ministers are warning against the delays, which may slow down the sustainable transition of the automotive sector.

READ MORE

EOL VEHICLES ON THE WAY TO RECEIVE AN UPDATED DIRECTIVE

The European Commission carried out an evaluation of Directive 2000/53/EC on end-of-life vehicles **[29]**, which has become outdated because of significant market developments and new targets for collection and recycling. The evaluation together with public consultation highlighted some shortcomings of the old document such as: lack of interconnection between the Member States on registration and de-registration of vehicles, the need for more detailed provisions to support the design of new vehicles to facilitate their dismantling and recycling, the absence of separate target for re-use, and the lack of a fully extended producer responsibility system established by the ELV Directive. The European Commission is expected to publish a proposal for an updated ELV directive in 2022.

READ MORE

The COBRA project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 875568.

References

[1] Marthaler Lukas, Buysse Maarten, Ierides Marcos, and McCready Amy, "MARKET INTELLIGENCE REPORT," Dec. 2021, Accessed: Feb. 27, 2022. [Online]. Available: www.baxcompany.com

[2] "New data on the lifecycle of lithium-ion batteries | LinkedIn." https://www.linkedin.com/pulse/new-data-lifecycle-lithium-ion-batteries-hans-eric-melin/ (accessed Jan. 13, 2022).

[3] I. Fernández Quesada, "THE CONCEPT OF REVERSE LOGISTICS. A REVIEW OF LITERATURE THE CONCEPT OF REVERSE LOGISTICS. A REVIEW OF LITERATURE 1," 2003. [Online]. Available: https://www.researchgate.net/publication/252429818

[4] "A Second Life For EV Batteries - YouTube." https://www.youtube.com/watch?v=yrkOWipbpQA (accessed Feb. 10, 2022).

[5] W. Bergh, "Mapping the European reverse logistics of electric vehicle batteries," 2020.

[6] A. H. Azadnia, G. Onofrei, and P. Ghadimi, "Electric vehicles lithium-ion batteries reverse logistics implementation barriers analysis: A TISM-MICMAC approach," *Resources, Conservation and Recycling*, vol. 174, Nov. 2021, doi: 10.1016/j.resconrec.2021.105751.

[7] F. Prevolnik, A. Z. Jönköping, A. Ziemba, and N. Akther, "The reverse logistics of electric vehicle batteries Challenges encountered by 3PLs and recyclers i Title: The reverse logistic of electric vehicle batteries," 2019.

[8] M. Slattery, J. Dunn, and A. Kendall, "Transportation of electric vehicle lithium-ion batteries at end-of-life: A literature review," *Resources, Conservation and Recycling*, vol. 174, p. 105755, Nov. 2021, doi: 10.1016/J.RESCONREC.2021.105755.

[9] European Commission, "Proposal for aREGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCILon shipments of waste and amending Regulations (EU) No 1257/2013 and (EU) No 2020/1056," 2021. doi: 10.1787/18166881.

[10] OECD, "GUIDANCE MANUAL FOR THE CONTROL OF TRANSBOUNDARY MOVEMENTS OF RECOVERABLE WASTES," 2009.

[11] L. Albertsen, J. L. Richter, P. Peck, C. Dalhammar, and A. Plepys, "Circular business models for electric vehicle lithium-ion batteries: An analysis of current practices of vehicle manufacturers and policies in the EU," *Resources, Conservation and Recycling*, vol. 172, Sep. 2021, doi: 10.1016/j.resconrec.2021.105658.

[12] T. O´Hara, "Navigating the Regulatory Maze of Lithium Battery Safety Global." [Online]. Available: www.intertek.com/energy-storage

[13] L. Kong, Y. Xing, and M. G. Pecht, "In-Situ Observations of Lithium Dendrite Growth," *IEEE Access*, vol. 6, pp. 8387–8393, Feb. 2018, doi: 10.1109/ACCESS.2018.2805281.

[14] N. S. Nembhard, "Safe, Sustainable Discharge of Electric Vehicle Batteries as a Pre-treatment Step to Crushing in the Recycling Process".

[15] R. Sojka, Q. Pan, and L. Billmann, “Comparative study of Li-ion battery recycling processes,” 2020.

[16] J. F. Hellmuth, N. M. DiFilippo, and M. K. Jouaneh, “Assessment of the automation potential of electric vehicle battery disassembly,” *Journal of Manufacturing Systems*, vol. 59, pp. 398–412, Apr. 2021, doi: 10.1016/j.jmsy.2021.03.009.

[17] K. Wegener, S. Andrew, A. Raatz, K. Dröder, and C. Herrmann, “Disassembly of electric vehicle batteries using the example of the Audi Q5 hybrid system,” in *Procedia CIRP*, 2014, vol. 23, no. C, pp. 155–160. doi: 10.1016/j.procir.2014.10.098.

[18] F. Lambert, “Nissan starts new program to replace old LEAF battery packs,” Apr. 26, 2018.

[19] A. Beaudet, F. Larouche, K. Amouzegar, P. Bouchard, and K. Zaghib, “Key challenges and opportunities for recycling electric vehicle battery materials,” *Sustainability (Switzerland)*, vol. 12, no. 14. MDPI, Jul. 01, 2020. doi: 10.3390/su12145837.

[20] “Proposed new rules on international shipments of waste - Lexology.” https://www.lexology.com/library/detail.aspx?g=54dc3254-46a4-4382-b33d-f33926ab0845 (accessed Jan. 14, 2022).

[21] X. Hu, F. Feng, K. Liu, L. Zhang, J. Xie, and B. Liu, “State estimation for advanced battery management: Key challenges and future trends,” *Renewable and Sustainable Energy Reviews*, vol. 114. Elsevier Ltd, Oct. 01, 2019. doi: 10.1016/j.rser.2019.109334.

[22] “Battery Passport set to spark true sustainable e-mobility | Umicore.” https://www.umicore.com/en/newsroom/battery-passport-for-sustainable-mobility/ (accessed Feb. 10, 2022).

[23] CodeSmith technologies, “Home - Battery Passport.” https://batterypassport.org/ (accessed Feb. 10, 2022).

[24] Everledger, “The ‘Battery Passport’ and the future of the auto industry.” https://everledger.io/the-battery-passport-and-the-future-of-the-auto-industry/ (accessed Feb. 10, 2022).

[25] IDIS, “The International Dismantling Information System.” https://www.idis2.com/ (accessed Feb. 10, 2022).

[26] Global Battery Alliance, “The Global Battery Alliance Battery Passport: Giving an identity to the EV’s most important component,” 2020.

[27] L. Albertsen, J. L. Richter, P. Peck, C. Dalhammar, and A. Plepys, “Circular business models for electric vehicle lithium-ion batteries: An analysis of current practices of vehicle manufacturers and policies in the EU,” *Resources, Conservation and Recycling*, vol. 172, Sep. 2021, doi: 10.1016/j.resconrec.2021.105658.

[28] E. Johansson, “Design for Assembly and Disassembly of Battery Packs.”

[29] European Commission, “COMMISSION STAFF WORKING DOCUMENT EVALUATION of Directive (EC) 2000/53 of 18 September 2000 on end-of-life vehicles,” 2021. Accessed: Jan. 04, 2022. [Online]. Available: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2021:0060:FIN:EN:PDF

NOT YET SUBSCRIBED?

CLICK HERE TO RECEIVE ALL FUTURE REPORTS

If you have any feedback or would like to contribute to the next edition contact cobra@baxcompany.com