Position paper

Resource efficiency for electric vehicle batteries

Strengthening ecodesign, reuse, repair and high-quality recycling

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Profile of Deutsche Umwelthilfe e.V. (DUH) (Environmental Action Germany)

Environmental Action Germany is a recognized German environmental and consumer protection association that has been actively campaigning for the preservation of our natural resources and the interests of consumers since 1975. We are politically independent, non-profit and active at national and European level. We are known, for example, for our role in uncovering the diesel scandal and introducing a deposit system for single-use beverage packaging in Germany. In the area of circular economy, we are committed to waste prevention, responsible consumption and a sustainable economy. Further information can be found at www.duh.de/englisch.

Introduction

The shift towards battery-powered vehicles plays a crucial role in reducing CO_2 emissions and air pollution in the transport sector. In the overall assessment, electric vehicles have a lower climate and environmental impact than comparable combustion vehicles.[1] However, electric vehicles are not a panacea, as their production, use and disposal also have an environmental impact. For example, the production of lithium-ion batteries (LIB) requires raw materials such as lithium, cobalt and nickel, the extraction of which is associated with significant environmental impacts (e.g. high consumption of water resources, release of pollutants and impact on ecosystems). It is therefore crucial to ensure that the energy transition does not merely lead to a **shift in environmental impacts.** Consistent implementation of the waste hierarchy has great potential to drastically reduce the environmental impact of electric vehicle batteries (EV batteries).

The **waste hierarchy is** an order of priority set out in the EU Waste Framework Directive, which should guide all legislation in the area of the circular economy. It stipulates that prevention and (preparation for) reuse[2] should be given priority over recycling and recovery in order to minimize adverse environmental impacts. As a result, there is significant potential to increase the resource efficiency of EV batteries particularly in the upper levels of the waste hierarchy, e.g. by reducing demand, promoting smaller and lighter batteries, substituting critical materials and advancing repair, reuse and effective collection as a prerequisite for high-quality recycling. Only a holistic approach with measures at all levels of the waste hierarchy can effectively minimize the environmental impact of EV batteries.

Waste hierarchy from the Waste Framework Directive

Insufficient integration of the waste hierarchy into European legislation

DUH believes that both existing legislation and current legislative proposals take insufficient account of the waste hierarchy and neglect essential resource efficiency measures.

The **EU Batteries Regulation** adopted in June 2023 sets out for the first time clear requirements for the entire life cycle of EV batteries, such as limiting greenhouse gas emissions during production or regulating the use of recycled materials. However, decisive measures to promote a long service life, repair and reuse structures as well as binding ecodesign specifications (reparability, reusability and recyclability) are missing.[3]

The Critical Raw Materials Regulation (CRMR) adopted in May 2024 also fails to achieve the goal of reducing resource dependencies through effective circular economy and the efficient use of primary raw materials.[4] Instead of prioritizing waste prevention, repair and reuse, the focus is on promoting recycling as the third stage of the waste hierarchy.

The EU Commission published a proposal for a regulation on circularity requirements for vehicle design and on management of end-of-life vehicles **(VDEoL)** in July 2023. The draft lacks measures to reduce vehicle size, waste prevention and concrete ecodesign requirements, although the proposed regulation aims to make the design of vehicles more sustainable. This is particularly problematic as the Ecodesign for Sustainable Products Regulation (**ESPR**) adopted in May 2024 excludes vehicles completely.

The implementation of the waste hierarchy in current legislation has decisive deficits

An important opportunity to strengthen the upper waste hierarchy for EV batteries would be a "**right to repair**". Important elements here are, for example, a repair-friendly design and good availability of spare parts and software updates. The proposal for an EU-wide right to repair was recently adopted by the EU Council. However, vehicles are not covered.

The deficits described regarding implementation of the waste hierarchy in current legislation pose a major problem. As the production capacities for EV batteries are increasing rapidly due to mobility shift required by climate policy, important legal framework conditions should now be created quickly in order to effectively limit the ecological consequences of the increasing resource requirements.

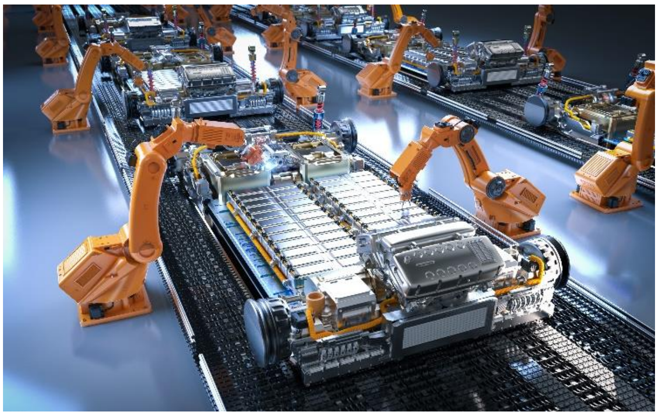
This paper presents necessary measures to strengthen the upper levels of the waste hierarchy in the field of electric EV batteries. It analyzes environmental potentials, addresses possible obstacles and shows solutions for an effective implementation of the measures.

Measures to promote the resource efficiency of electric vehicle batteries at the upper levels of the waste hierarchy

1. Improvements in ecodesign

The life cycle assessment of EV batteries is already significantly influenced during the design and manufacturing phase. The production of conventional LIBs requires the energy and environmentally intensive extraction of a large number of critical raw materials such as lithium, cobalt and nickel. In addition, the production of these batteries generates greenhouse gas emissions of 40 - 350 kg CO_2 per kWh of battery capacity.[5] It is therefore crucial to ensure that EV batteries are used as long as possible in order to spread these environmental impacts over a long period of use. Relevant aspects for the resource-efficient ecodesign of EV batteries are therefore the environmentally friendly use of raw materials, a long service life and good reparability, reusability and recyclability.

The new **EU Batteries Regulation** sets out some welcome ecodesign requirements for EV batteries, such as recycled content targets (Article 8) and requirements for electrochemical performance and durability (Article 10). In DUH's view, however, these provisions must be supplemented by further ecodesign aspects and relevant details must be specified in delegated acts.



The ecodesign of EV batteries must be enshrined in law

Economical use of raw materials

As few primary raw materials as possible should be used in the production of EV batteries and the materials used should have the lowest possible environmental impact in the countries of origin. The use of particularly problematic materials, such as cobalt or lithium, should be minimized as far as possible in battery production. Against this background, the current trend towards a continuous increase in the weight of vehicles and lithium-ion batteries is highly problematic.[6] However, new battery technologies that substitute critical raw materials can have positive effects (see section 7).

In order to address these points, DUH proposes first establishing a **monitoring** system to better record the raw material requirements in the production of EV batteries (in analogy to the declaration of the CO_2 footprint or the recycled content in the EU Batteries Regulation Art. 7 & 8). All raw materials used, their recycled content and the countries of origin of the primary raw materials should be disclosed, for example via the part of the battery passport that can also be viewed by consumers. In the opinion of DUH, the transparency obligations set out in Article 8 (1) of the EU Batteries to apply from 2028, do not go far enough.

Following this monitoring, a possible **limitation of the use of primary raw materials** in battery production should be investigated, for example in relation to the total battery weight (e.g. as a fleet limit) or by limiting the mass of certain particularly problematic raw materials. There may also be specifications for a product/fleet-specific material footprint. Corresponding regulations are missing in the EU Batteries Regulation, in the draft for the VDEoL and are not planned for the ESPR either.

Recycled content

The use of **recycled content** in manufacturing can contribute significantly to reducing the environmental impact of products. Secondary materials such as steel, aluminum, cobalt and nickel are already available on the market for EV batteries[7], but high-quality recycling processes for used batteries and the use of these recyclates for battery production must be further promoted. In particular, the use of secondary lithium plays a decisive role here, as the battery cell technologies established on the market are based on this raw material and demand is increasing dramatically.[8] Currently, secondary lithium is almost exclusively produced from industrial waste. In Article 8(2) of the EU Batteries Regulation, recycled content targets for lithium, lead, cobalt and nickel in EV batteries will be legally required for the first time from 2032 on and increased again from 2036. This is an important signal for the recycling industry to build up corresponding capacities. From DUH's point of view, however, a decisive aspect here is the calculation method: waste from battery production (post-industrial recycled content (PIR)) should not be included in the recycled content targets so that this measure actually promotes the use of post-consumer recycled content (PCR), the recycling of which is currently still economically unattractive. There are generally already sufficient economic incentives for the recycling of production waste. Excluding PIR from recycled content targets would also create incentives to make more efficient use of the resource potential of LIBs from e-waste and portable batteries.

There is also considerable potential in the use of recycled plastics, which is why binding targets for the use of plastic recyclates in EV batteries should also be set. The EU draft of the VDEoL (13.07.2023) proposes such targets for vehicles for the first time, but the regulation would not apply to batteries. When calculating recycled content targets for plastics, it should also be noted that pyrolysis or gasification technologies should not be included.[9]

Durability

A high durability is a key aspect for the sustainability of EV batteries, as it reduces the environmental impact of resource consumption, production and disposal through a longer service life. Durability of EV batteries is also an important basis for the profitability of reuse or repair structures. Batteries should be designed in such a way that they are insensitive to certain defects or rapid wear and tear. DUH is calling for a legally guaranteed **minimum service life of 15 years or a mileage of 300,000 km**, so that under normal use at the end of this period, a residual capacity of 70 percent is still available.

Since the usage and **charging behavior** of some battery chemistries (e.g. LIBs) also has a very significant influence on wear[10] , careful charging behavior should be promoted through charge management and information for consumers.[11] Alternative battery technologies also have considerable potential to achieve a longer service life (see section 7).[12]

The **EU Batteries Regulation** (Article 10) is an important foundation for regulating the performance and durability of EV batteries. Parameters such as capacity loss and the expected service life of the battery will be limited. These specifications must now be specified in delegated acts as quickly as possible so that they become timely effective.

Reparability

Good reparability is an important basic requirement for a long service life of EV batteries and their reuse. It must therefore be taken into account in

Exploiting the potential of resource conservation through repair the design of the battery. The EU Batteries Regulation (Article 77 or Annex XIII) contains requirements for manufacturers to provide information on dismantlability. However, DUH believes that this is not sufficient to ensure good reparability. This would require design specifications that stipulate a modular structure and the **removability and replaceability of individual battery modules**. The safety concerns frequently cited by the industry with regard to interchangeability at cell level should be scientifically examined by the EU Commission in order to avoid giving away the resource-saving potential of such repairs. In this context, the often-applied integration of so-called cell-to-pack modules in production is problematic, as it makes repair considerably more difficult.

Article 7 of the draft VDEoL (13.07.2023) contains individual provisions on the **removability and replaceability of EV batteries**, such as ensuring the non-destructive removal of the battery from the vehicle. However, especially for the purposes of repair and re-use, EV batteries must be easily and non-destructively removed and replaced. Other important measures to promote repair are presented in section 3.

Reusability

First and foremost, the reuse of EV batteries requires good technical prerequisites. For this, subsequent reuse must be taken into account in the design process from the outset. Important criteria here are, for example, a long service life, a modular design that is as standardized as possible and good dismantling and reparability. There should also be a ban on software blocks making reuse more difficult. Further measures to promote reuse - particularly with regard to the necessary data provided by manufacturers - are presented in section 2.

Modular design of an EV battery can improve reparability and reusability

Recyclability

Recyclability is an important sustainability criterion, as it helps to close raw material cycles and reduces the use of primary resources. It must therefore be taken into account during the design of EV batteries, without neglecting criteria such as durability, reparability and reusability. Important measures to promote the recyclability of EV batteries include promoting a good dismantlability of battery components (e.g. by avoiding material composites), the use of uniform materials, good labeling and a low level of pollutants and impurities.

For the first time, the **EU Batteries Regulation** sets out requirements for the labeling of batteries, e.g. with regard to the chemical composition and the hazardous substances and critical raw materials contained (Article 13). Information on dismantling is to be provided via the battery passport (Article 77 or Annex XIII). These welcome requirements must now be quickly put into practice and supplemented by binding requirements for recycling-friendly battery design.

Standardization

Further development of standardization in the field of EV batteries and corresponding components is necessary to improve resource efficiency. The EU Batteries Regulation completely lacks provisions to promote a standardized structure and design of EV batteries and components. The draft for a VDEoL (13.07.2023) also does not contain any approaches to promote a standardized design of EV batteries.

The standardization of batteries and associated components can make it easier for them to be used for several vehicle types and thus also supports their long-term availability. In addition, the subsequent upgrading of vehicles with newly developed batteries can be promoted, thus enabling a longer vehicle service life. In particular, a standardized design of EV batteries and cell packs is relevant for promoting the **reuse** of EV batteries, as similar designs and functionalities significantly reduce the cost of second-life applications. Standardization should be supported as far as possible within the manufacturers' product lines, but also across manufacturers. Political instruments should promote these developments. In addition to construction and functionality, standardization is also necessary with regard to data formats that are made available to actors in the fields of reuse, repair and recycling.

Further development of standardization can contribute to resource conservation

Integration of ecodesign aspects into fee structures

License fees that are directly linked to the environmental impact of EV batteries can be a valuable instrument for promoting the aforementioned ecodesign criteria. This **eco-modulation** of license fees should be designed so effectively that manufacturers actually receive incentives to design products more in line with ecological criteria. Such fees should also be made visible to consumers and the link to ecodesign criteria should be clearly communicated (so-called visible fees) in order to influence purchasing behavior. DUH proposes parameters such as battery weight, durability, reparability, reusability, use of reused parts and recycled materials as well as recyclability as important parameters to consider during eco-modulation, e.g. through a bonus/malus system.

2. Promotion of reuse

At the end of their first life as a traction battery, EV batteries often still have a very good storage capacity of between 70 and 80 percent[13,14] and are therefore suitable for mobile or stationary use in second-life (SL battery). Possible second-life applications include energy storage systems for photovoltaic or wind power plants, emergency power systems in the municipal power grid or primary control power in power grid operation.[15] There will be a great demand for such energy storage systems in the future electricity grid due to the expansion of renewable energies. In order to exploit this potential, the conditions for good reusability of EV batteries and good infrastructures should now be created.

Potential to reduce environmental impact through reuse

Reusing an electric vehicle battery is generally the more environmentally friendly option compared to recycling, as the environmental impact of raw material extraction, battery production and disposal compensated by a longer service life. When LIBs are reused, materials such as lithium, cobalt, nickel, manganese, copper, aluminum and graphite remain in use, while these materials would only have been partially recovered during recycling. As reuse reduces the need for newly produced batteries, the overall environmental impact is enormous, for example in terms of greenhouse gas emissions, water consumption, acidification and the consumption of abiotic resources.[16] Additionally, the energy required to recycle and produce a new battery can be delayed, resulting in significant energy savings[17].

Market for reuse

If the EU is to meet its declared goal of climate neutrality by 2050, an estimated 970 GWh of grid-wide installed battery storage capacity will be required by 2030. This would require a significant increase in annual additions, averaging almost 120 GW per year between 2023 and 2030.[18] It makes a lot of sense to fully exploit the potential of used EV batteries to meet this demand. In 2030, around 120,000 EV batteries from electric cars will be generated annually in the EU as end-of-life batteries, which have a storage capacity of approximately 8 GWh.[19] Companies have already recognized the **potential of second-life EV batteries.** Box 1 presents a selection of current business models in the field of vehicle battery reuse.

In addition, **insurance companies** are increasingly important players who, for example, are very interested in the reuse of vehicle parts such as EV batteries after an accident for cost reasons. A best-practice example is Sweden, where insurance companies are already cooperating with reuse players and strengthening the reuse spare parts market for electric vehicles.[20]

Overcoming obstacles in practice

Automotive and battery manufacturers currently often prefer a rapid return of used batteries in order to recycle raw materials quickly, as there is an economic interest in the battery materials for new sales.[21] **The complexity of the reuse process**, e.g. due to a lack of data, different battery cell technologies and safety concerns, is also often cited as an argument as to why batteries are not suitable for reuse.[22] In particular, it is the **responsibility of producers** to provide the technical data required for safe reuse. In addition, poor dismantlability, a design that is difficult to repair and a large number of different battery formats and cell technologies make it difficult to prioritize environmentally friendly reuse. It is important to quickly overcome these practical obstacles to the reuse of EV batteries through policy instruments and market developments.

DUH does not see any contradiction between achieving **recycled content targets and reuse:** On the one hand, the amount of used batteries available for recycling is decreasing, but at the same time the demand for new batteries to be produced is also decreasing, so that the amount of recyclates available for new production should hardly be influenced by increased reuse. However, political instruments to promote recycling should be designed in such a way that they do not hinder reuse.

» **BeePlanet** (energy storage system production)

The Spanish provider BeePlanet manufactures energy storage systems that reuse EV batteries. The batteries are used for photovoltaic, wind and off-grid installations for e.g. the residential, commercial or industrial sectors. BeePlanet has direct agreements with automotive suppliers/manufacturers for the collection and reuse of used EV batteries. Further information can be found at https://beeplanetfactory.com/en/.

» **Connected Energy** (energy storage system production)

The British company Connected Energy designs and develops energy storage systems using used batteries from electric vehicles from automotive partners. Their second life systems have a range of applications including storing renewable energy and managing energy loads for electric vehicle charging stations for commercial, industrial and public authorities. Further information can be found at https://connected-energy.co.uk/.

» **Circunomics** (software and platform service provider)

The German company Circunomics offers software for analyzing the condition of used EV batteries and operates a marketplace for second-life and recycling. The platform supports the networking of stakeholders and promotes reuse applications for energy storage systems or micromobility, for example. Further information can be found at https://www.circunomics.com/.

» **Betteries AMPS GmbH** (manufacture of mobile energy systems)

The German company Betteries offers alternatives to fuel-powered generators by reprocessing used electric EV batteries at module level. The modular energy systems can be used in various industry segments such as the construction industry, civil and disaster protection, as well as the film and entertainment industry. Further information can be found at https://betteries.com/.

» **Watt4ever** (production of energy storage and drive systems and generators)

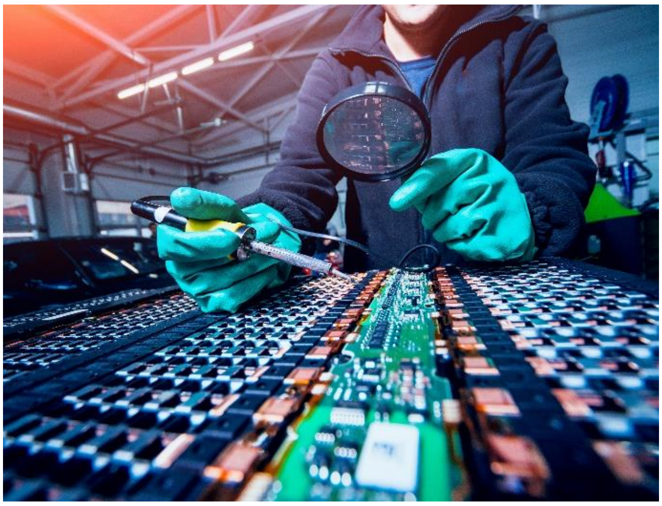
The Belgian company Watt4Ever offers high-quality second-life battery modules for private individuals and companies. The applications range from large storage systems to modules for electromobility or storage applications for companies. Further information can be found at https://watt4ever.be/.

Box 1: Exemplary business models for second-life applications of EV batteries

Necessary measures to promote reuse

In addition to good technical prerequisites through ecodesign (see section 1), independent players need easily accessible **manufacturer information** for successful and economical reuse. To this end, they must collect the necessary technical data and make it available to independent stakeholders (e.g. basic technical data, data on dismantling, data on the "state of health"). This is the only way to ensure that important events that could affect the life and safety of the battery are properly taken into account when testing a vehicle battery for reusability. The EU Batteries Regulation contains initial welcome requirements for tracking harmful events, e.g. number of deep discharges, period under extreme temperatures, and period of charging under extreme temperatures (Article 14 and Annex VII). However, manufacturers should allow independent actors not only "read access" to the battery management system (BMS) (Article 14), but also **"control access"** in order to integrate the BMS into the second-life application and make optimal use of the batteries. Manufacturers should be legally obliged to provide all this data without financial and structural hurdles for independent players and in a standardized form. The battery passport is a useful instrument for this.

The EU Batteries Regulation specifies target values for the recycling efficiency and material recovery of EV batteries (Article 71), but there are no binding **reuse targets**. The current regulation results in a biased focus on recycling and contradicts the waste hierarchy. DUH calls for the introduction of such reuse targets, the specific level of which should be determined by the Commission on the basis of market data and should gradually increase. Furthermore, these targets should not only be mandatory for the Member States, but also for producers and their collective organisations. This would create appropriate incentives to create structures for reuse. To promote reuse, DUH also proposes introducing an **obligation to check the reusability** of used EV batteries before they are dismantled. In the case of reusability, the battery must be removed in a non-destructive manner and the battery must be given to (preparation for) reuse.



Reconditioned EV batteries are often still suitable for renewed stationary or mobile use in their "second life"

In Europe, the decision as to what happens to an accident-damaged vehicle is often in the hands of the **insurer**, but in Germany, it is up to the owner. As during the expansion of electromobility initially mainly batteries from accident vehicles are available for reuse, it may make sense to promote the role of insurance companies in order to strengthen the spare parts market and cooperation with reuse players.

In order to establish reuse structures timely, **economic incentives** for more reuse should also be created. Possible instruments in this field would be tax reductions for repairs and the use of reused EV batteries. Public procurement should also commit to prioritizing the use of second-life batteries and make this a condition of funding programs for stationary energy storage systems. Rental and leasing programs that provide customers with reused batteries and thus enable long-term use could also be promoted.

3. Promotion of repair

Regular maintenance and repair significantly extends the service life of EV batteries and can sometimes prevent premature complete replacement. Repair reduces the need for batteries and thus minimizes the environmental impact associated with their production (e.g. resource requirements, energy requirements). Therefore, optimal conditions should be created for the repair of EV batteries.

Overcoming obstacles in practice

Currently, there is already a shortage of affordable repair solutions for EV batteries on the market, as there is a lack of **diagnostic infrastructure** to accurately diagnose the condition of EV batteries and identify appropriate repair options.[23]

The **cost of repairs** also plays a decisive role in the market for insurance companies and vehicle owners to opt for a repair instead of a complete replacement of EV batteries. According to the German Insurance Association, repair costs for electric vehicles between 2019 and 2021 were 30 - 35 percent higher than for comparable combustion vehicles.[24] The current high costs are due to the low distribution of electric vehicles and safety measures for dealing with damaged lithium-ion batteries. However, the expansion of the market for electric vehicles and new types of batteries mean that these costs can be expected to fall in the future. Additionally, electric vehicles need to be repaired less frequently than comparable combustion engines, as fewer mechanical parts are used, which further reduces costs.[25] Another very relevant parameter in terms of repair costs is usually the price of spare parts.

Essential conditions for good reparability must be laid at the stage of design (see section 1). **Software aspects** are also becoming increasingly relevant, as electric vehicles are becoming more and more like electrical appliances whose reparability is often limited by software dependencies.[26] In this context, repair-unfriendly manufacturer practices such as part pairing or coding are also problematic. The latter are increasingly being used to control various parts and components in vehicles.[27]

Necessary measures to promote repair

The EU Batteries Regulation has failed to establish a good basis for a strong repair infrastructure for EV batteries. Without sufficient requirements, a situation similar to that of electrical appliances could arise, where fully functional products have to be discarded prematurely at high environmental impacts because they cannot be repaired or the costs of repair are too high.

Binding ecodesign specifications for the reparability of EV batteries are an important basis for repair (see section 1). The **availability of spare parts** also plays a decisive role. Relevant criteria here are the guaranteed availability period from product purchase, the procurement channel, the delivery time and the price. The price of spare parts should be in appropriate proportion to the original battery price. DUH demands that spare parts for EV batteries must be available for 15 years after the battery purchase. In addition to spare parts, software applications should also be subject to these obligations and be made available for at least 15 years, ensuring safe use without restricting functionality.

Repairs should not only be feasible for manufacturers, but also for (certified) **independent repair workshops** in order to establish a manufacturer-independent repair infrastructure and thus promote **low repair costs**. Therefore, these independent players should be provided with non-discriminatory access to spare parts, software updates, tools as well as repair and dismantling instructions. Anti-repair practices from manufacturers such as part pairing must be banned, as independent repairers often lack access to the necessary codes or pairings.[28] In addition, EV battery repairs should be tax-privileged to favor repair over battery replacement further.

Overall, a **right to repair** is needed that guarantees the legal requirements for repair described above. DUH criticizes the fact that vehicles are not within the scope of the adopted ESPR and will therefore not fall within the scope of the Right-to-Repair Directive.

4. Successful battery passport and strong consumer information

From 2027, the **EU Batteries Regulation** will require every EV battery placed on the market in the EU to have a battery passport (Article 77). The battery passport is intended to enable various stakeholders to obtain relevant information about the battery. For example, in future consumers will be able to get information on the material composition or the CO_2 footprint. The introduction of the battery passport is an important step towards promoting repair, reuse and recycling and making it easier for consumers to make ecological purchasing decisions. However, it is now important that maximum transparency is achieved for consumers, repair, reuse and recycling companies in the subsequent detailed regulation.

The data stored in the battery passport is particularly relevant for **repairs** and in the case when passing on the EV battery for **reuse.** Thus it promotes the service life and safety of batteries during use. The data required for repair and reuse is described in detail in sections 2 and 3. For **consumers**, it is crucial that the information on the battery is easily accessible at the time of purchase and via product labeling, and that information on the origin and type of raw materials, recycled content, CO_2 footprint, pollutant content, expected service life and reparability is included in the battery passport. Reparability could be assessed using a repair index/label similar to the ecodesign regulations for smartphones and tablets.

In addition, the battery passport offers enormous potential for obtaining more information about the **life cycle of specific batteries.** For example, data on the manufacturer and distributor as well as maintenance work, repairs (including defects) and resales should be stored in the battery passport. At the end of their life, the battery passport could also be used to ensure proper disposal, for example by requiring owners of EV batteries to provide a disposal certificate officially. The battery passport also requires good **harmonizing and networking with other product passports**, e.g. with the planned product passport for vehicles.

Battery passport: Important instrument for more transparency

5. Extended product responsibility and reliable collection

According to the **EU Batteries Regulation** (Article 61), manufacturers and producer systems of EV batteries must take back waste EV batteries free of charge from August 2025 and ensure that they are collected separately and sent for reuse or recycling. Additionally, dealers will be obliged to accept EV batteries at the point of sale and hand them over to the manufacturers from that date (Article 62).

DUH very much welcomes the important basis of the EU Batteries Regulation for a **system of extended product responsibility (EPR)** for EV batteries laid down by the EU Batteries Regulation. However, beyond setting obligations for collection and recycling, a comprehensive framework for EPR is needed to minimize environmental impacts from production to disposal of EV batteries. An EPR system should also oblige manufacturers to promote repair and reuse in line with the waste hierarchy, for example through binding reuse targets and mandatory tests for the reusability of end-of-life EV batteries. In addition, manufacturers should take more responsibility for raising consumer awareness of environmentally friendly behavior.

DUH supports the "producer-driven model" and "competitive PROs" models for EPR developed and favored as part of a study on textiles. The models described enable more binding targets to be met (e.g. with regard to reuse and recycling) and simpler enforcement.[29] DUH welcomes the option provided in the EU Batteries Regulation for member states to make the fulfillment of product responsibility through **collective systems** mandatory. The formation of collective systems for the implementation of producer responsibility should be mandatory throughout the EU, as this can considerably facilitate enforcement within the framework of product responsibility and thus contribute to better fulfillment of producer obligations.[29] Collective systems can also be used to integrate eco-modulation mechanisms more easily (see section 1).

Reliable collection is also the basic prerequisite for proper reuse or recycling of EV batteries. In contrast to portable batteries, these batteries are not disposed of via domestic waste collection in the event of incorrect disposal, but rather through illegal resale inland and abroad, where proper end-of-life recycling is no longer guaranteed. Incentives are therefore also needed for consumers, workshops and insurance companies to dispose of EV batteries properly. In this context, DUH considers a deposit system or an obligation to provide certificate of disposal to be suitable instruments. In addition, a system is needed that enables better traceability of EV batteries. This could be based on the battery passport (see section 4).[30]

To restrict **illegal exports** of EV batteries, a clearer classification of end-of-life batteries as hazardous waste is needed, as well as clearer responsibilities if batteries become waste. Illegal exports often involve entire vehicles. According to current estimates, between 3.4 and 4.7 million end-of-life vehicles are illegally exported from the EU to Africa every year, in addition to 1.8 million confirmed exports.[31] The VDEoL draft (13.07.2023) contains valuable approaches to curb the illegal export of EV batteries through better definitions (e.g. on roadworthiness). However, these measures must be complemented by effective official and customs controls as well as sanctions in order to be successful.

However, the **export of roadworthy vehicles** outside the EU remains legal. In these cases, DUH is calling for the EPR fees that manufacturers save by exports to be made available to the receiving countries for the operation of waste management systems.[32] Producer responsibility should only end when the vehicle or battery has been demonstrably recycled to a high standard. It is also necessary to only allow these exports to countries that can demonstrate similar environmental standards for recycling as in the EU. The VDEoL should also stipulate that relevant information, e.g. on state of health of the battery, must be passed on to receiving countries when used EV batteries are exported.

6. High-quality recycling

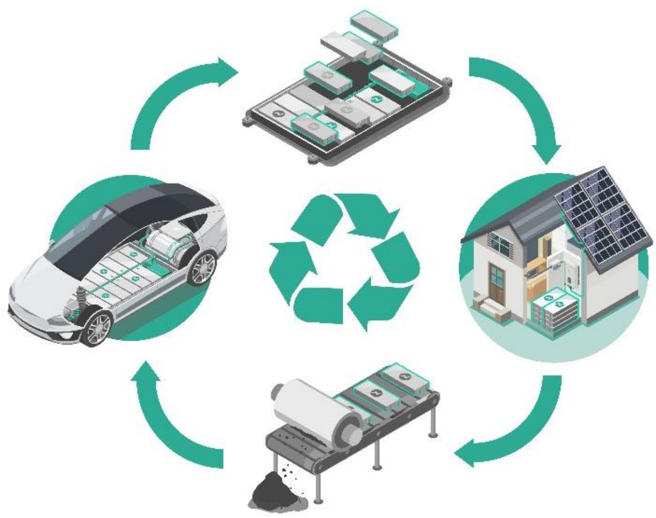
Currently, EV batteries are usually made from primary raw materials, the extraction of which is associated with significant environmental impacts. The demand for primary raw materials should be reduced not only by promoting reuse measures but also through efficient recycling. This would also promote the regional supply of raw materials.

A basic prerequisite for efficient recycling structures in Europe are **high-quality collection structures** (see section 5). It is also important that recyclable materials are not exported for inferior recycling (e.g. through illegal exports of end-of-life vehicles). In this context, DUH recommends classifying the "black mass" generated during recycling as hazardous waste in order to prevent exports to countries with poor environmental standards. Currently, the lack of treatment capacities in the EU means that a large proportion of the black mass generated in Europe is exported to Asia.[33]

A strong recycling market is needed in Europe in order to optimally recover the recyclable materials contained in batteries after the longest possible period of use and to meet the recycling efficiency and recovery targets set out in the EU Batteries Regulation (Article 71). The **CRMR** sets targets for recycling in the EU for the first time: At least 25 percent of the annual consumption of strategic raw materials should be recycled by 2030. DUH calls for such targets to be set not only for the member states but also for specific players (e.g. producers) in order to achieve greater commitment.

A recycling-friendly design also plays an important role (see section 1). Relevant **information for recyclers**, e.g. on dismantling or the raw materials contained, should be provided in the battery passport and on the battery labels. The **quality of the recycling** also plays an important role: the recovered materials can only be used for the production of new EV batteries if they are of "battery-grade" quality. Legal requirements must therefore absolutely prevent the downcycling of battery materials (e.g. for use in road construction).

DUH welcomes the fact that **material-specific recycling targets** for lithium, cobalt, nickel, copper and lead have been set for the first time in the EU Batteries Regulation. This instrument promotes



Following a second life, high-quality recycling can make an important contribution to reducing the demand for resources the recycling of currently less profitable materials (e.g. lithium and cobalt) and supports the further development of recycling processes.

However, in order to close material cycles, it is also essential to promote the use of secondary materials in production. Political instruments should ensure that **secondary raw materials** become competitive with primary raw materials. **Recycled content targets** are an important instrument for promoting the timely establishment of high-quality recycling structures (see section1).

7. Promotion of research and development

Technological progress and research into alternative battery cell technologies are also expected to help reduce the need for critical raw materials such as lithium or cobalt in the future. Currently, there is considerable potential to improve the resource efficiency of EV batteries through various technological developments.

The **lithium-ion battery** is the cell technology currently dominating the market. It is characterized by a high energy and power density and is therefore particularly suitable for mobile applications.[34] The advantages of LIBs are that they can be charged quickly and have a good durability, although the latter depends heavily on storage and usage behavior.[10,35] From an environmental point of view, the high demand for critical raw materials for LIB technology is particularly problematic. If used, stored, transported or disposed of improperly, LIBs can cause fires.

Common LIB technologies are **NMC** (nickel-manganese-cobalt), **NCA** (nickel-cobalt-aluminum) and **LFP** (lithium-iron-phosphate). NMC/NCA batteries are currently mainly used in Europe for electric vehicles with long ranges and high performance. LFP batteries avoid the use of the critical metals cobalt, nickel and manganese and are more durable than classic LIBs.[36] Iron and phosphate are good available resources and easy to recycle. [37,38] LFP batteries are also less flammable than NMC/NCA batteries and therefore safer. [39] However, LFP batteries still require large quantities of critical lithium. Technically, LFP batteries also have a lower energy density than conventional LIBs and therefore require more space. They are therefore primarily used for stationary energy storage or are suitable for smaller vehicles such as motorized two-wheelers or small cars.

One LIB technology that has not yet been commercialized is the **solid-state battery**. Technical advantages include high energy density, safety, short charging times and longer ranges compared to classic LIBs. Solid-state batteries also offer clear advantages from an environmental point of view due to their durability, more compact and lighter construction and the avoidance of cobalt, among other things. [40,41]

Research is also focusing on an alternative cathode material for batteries in order to avoid the need for critical lithium. **Sodium-ion batteries (SIBs)** are particularly promising here because the first electric vehicle with this battery technology has been available on the market since January 2024.[42] Sodium is widely available on earth and is not critical in terms of extraction, which gives SIBs clear environmental advantages over LIBs. SIBs are also non-flammable and therefore safe even at high and low temperatures.[43] SIBs can also achieve a long service life. A technical disadvantage is the lower energy density compared to LIBs and the associated higher space requirement of SIBs.[44,45]

Other metal-ion batteries that are currently being developed are aluminum-ion and magnesium-ion batteries.[38] These metals are abundantly available and can further reduce the need for critical raw materials. The magnesium-ion battery also promises a significant reduction in the CO_2 footprint. However, there are still some technical challenges to be solved with regard to these metal-ion batteries for mobile applications. Alternatives such as metal-sulphur and metal-air batteries are also currently being researched.[38] However, in order for these technologies to be used in the passenger car segment in the long term, technical hurdles such as operation at low temperatures or rechargeability still need to be overcome.

New battery cell technologies such as the solid-state battery can significantly reduce the need for critical raw materials for battery production

Europe should **promote the development and establishment of new battery technologies** that are associated with lower environmental impacts. An important criterion here is minimizing the use of critical raw materials such as lithium, cobalt, nickel or manganese. From an environmental point of view, a low CO_2 footprint, a long service life, high energy efficiency and a low fire risk should also be achieved. Innovations are also needed to improve the reparability and recyclability of batteries.

A one-sided focus of the EU market on one battery cell technology should be avoided wherever possible. Good conditions should be created to ensure that new battery types with a demonstrably lower environmental impact can quickly establish themselves on the market.

8. Adaptations in mobility behavior

Adjustments in mobility behavior also have enormous potential to reduce resource requirements in the battery sector, especially since corresponding measures start at the top of the waste hierarchy. Measures here may on the one hand relate to a reduction in the number of passenger cars and on the other hand to individual vehicle characteristics.

A shift from combustion engines to electric drives is necessary for both climate protection and overall ecological reasons.[1] However, this does not mean that every car currently registered should be replaced by an electric car. DUH is calling for **the total number of passenger cars to be halved in the long term** as part of a fundamental change in mobility. To achieve this, walking, cycling and local public transport must be significantly promoted and made more attractive, facilitating the reduced use of private vehicles. Political instruments to promote a mobility transition include, e.g. adjustments of taxes and parking fees, a reduction in public transport, a mileage-based toll and the abolition of counterproductive subsidies such as the diesel privilege or company car tax in Germany.

Reducing the total number of cars as part of a fundamental change in mobility also helps to protect resources

Electric cars can only fully exploit their ecological advantages over combustion engines if they are as small and light as possible. **Reducing the weight or size of vehicles and LIB-batteries** is therefore another important lever for more resource conservation in the passenger car segment. So far, there have been insufficient political measures to reduce the proportion of vehicles with particularly high resource requirements (such as SUVs and off-road vehicles). Possible instruments would be, for example, taxes, parking fees or environmental zones that take vehicle weight into account. Beyond that, there is currently a lack of ecodesign specifications aimed at reducing vehicle weight overall (see section 1).

9. Binding resource reduction targets

In order to achieve greater commitment in the area of resource protection, DUH calls for the political anchoring of resource protection targets at EU level and in the member states (e.g. a material footprint reduction target). Such a regulation could be designed in the same way as climate legislation and set sub-targets for certain sectors - such as the mobility sector. Austria has already set corresponding resource protection targets in law.

A resource conservation target in the transport sector would have the advantage that the most effective measures - presumably at the upper end of the waste hierarchy - would make the greatest contribution to achieving the target and would therefore be prioritized. However, it is important that the targets are also **made binding.** For example, the targets could become binding for producers, who could then choose to take measures to improve resource efficiency (e.g. a reduction in vehicle weight).

However, resource protection targets should not relate exclusively to the critical raw materials required for a drive transition in order to avoid creating barriers to the shift to electromobility. In order to achieve greater resource efficiency in the field of critical raw materials, political **targets** could be set **for sustainable consumption** in certain areas (e.g. with regard to the calculated per capita consumption for vehicles or electrical appliances).

10. Reliable enforcement

Regulations for EV batteries can only be effective in protecting the environment and human health if they are effectively implemented and monitored. Therefore, enforcement authorities must be provided with **sufficient resources** to enable them to carry out their own measurements, plausibility checks and unannounced inspections. DUH also recommends that enforcement and monitoring tasks may be established across the EU in some overarching areas in order to pool expertise, network stakeholders and **harmonize enforcement practices in the EU**.

Currently, there are already considerable **enforcement deficits** in the area of batteries, particularly with regard to illegal exports or the full inclusion of manufacturers in EPR systems. There is also partially a lack of effective sanction mechanisms, e.g. certain violations are not classified as administrative offenses in German battery law. Especially well performing economic players highly depend on successful enforcement, as otherwise they will be forced out of the market by companies with lower environmental standards.

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