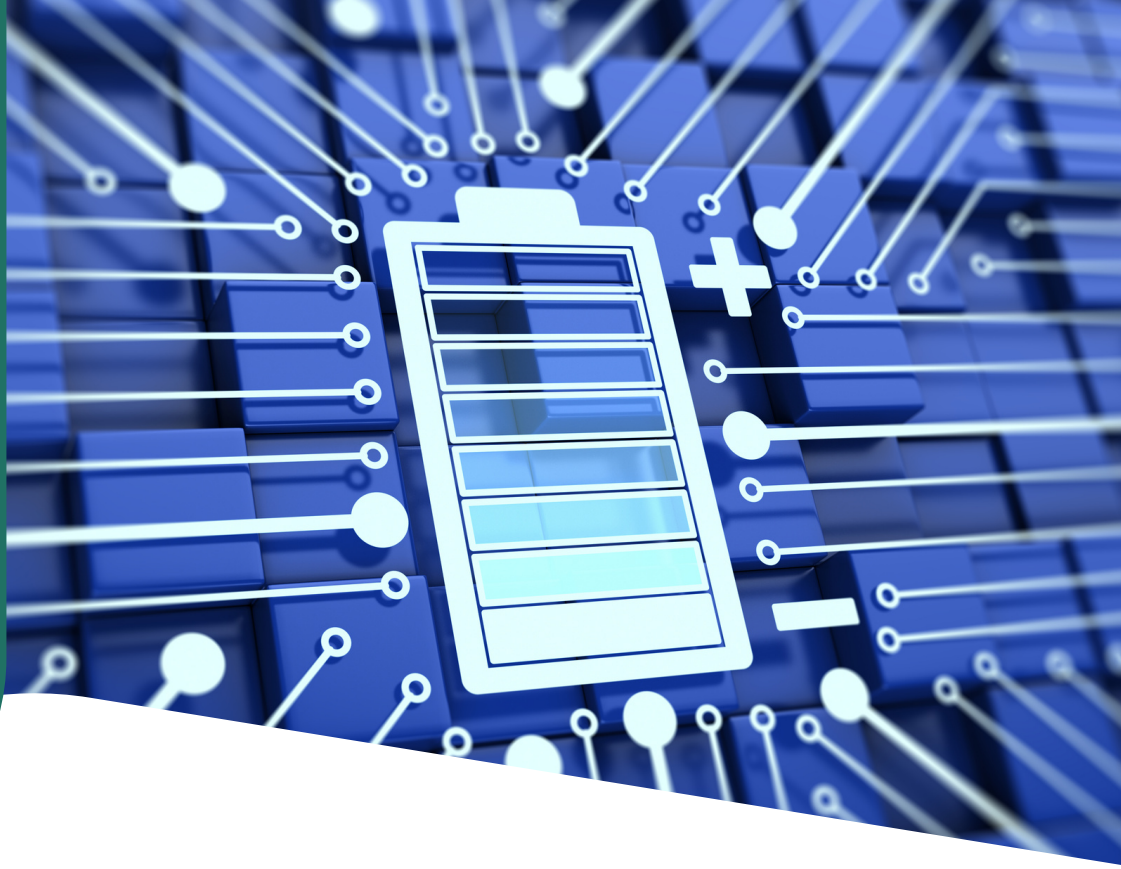

IMPLEMENTING THE EU DIGITAL BATTERY PASSPORT

Opportunities and challenges for battery circularity

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SUMMARY

Introduced as part of the new EU regulatory frameworks for ecodesign and batteries, the digital product passport (DPP) supports the collection and sharing of product-related data among supply chain actors. As the first tool of this kind globally, it aspires to address existing information gaps for products and components throughout global supply chains, thus becoming a key enabler for circular business models.

Produced through the EU-funded BATRAW project that develops circular approaches for electric vehicle batteries, this CEPS In-Depth Analysis paper delves into the new EU regulatory framework for batteries and the expanding EU DPP landscape. It identifies key opportunities and challenges for battery passports based on qualitative data collected from companies at different segments of the battery value chain.

There are a growing number of initiatives within the evolving EU DPP landscape that are developing proof of concepts or pilot cases. In addition to batteries for which the passport will be a legal requirement as of 2027, these initiatives include many other sectors including textiles, construction and electronics. This suggests that interoperability and alignment between the different DPP initiatives is important. Such initiatives can also facilitate multi-stakeholder collaboration and provide inspiration and lessons for other product groups beyond batteries.

The qualitative empirical data suggest that the digital battery passport can help break down information silos among supply chain actors and support recycling and reuse processes. It also provides opportunities for increasing transparency about carbon footprint impacts across battery supply chains, whilst creating a level playing field with horizontal requirements for all supply chain actors irrespective of their origins.

Simultaneously, several implementation challenges have also emerged. These include confidentiality concerns and the existence of data silos between battery supply chain actors, a lack of standards to ensure interoperability of data, concerns about reliability and the validity of collected data, and a lack of clarity regarding battery passport responsibilities at different end-of-life stages. The paper recommends that more clarity be provided about battery passport-related responsibilities, that passport data interoperability be supported, and that a platform be created for sharing best practices of battery passport initiatives.

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1. INTRODUCTION

Ever since the circular economy concept emerged in the EU policy debate in the early to mid-2010s, there has been much discussion about the need to increase transparency across supply chains to accelerate the transition to a circular economy. The first Circular Economy Action Plan (CEAP) identified the limited exchange of information across supply chain actors as a stumbling block to achieving circularity (European Commission, 2015). The second CEAP suggested that digital technologies can be a driver for improved availability of product-related information (European Commission, 2020). Different studies using empirical data from companies that implement circular business models (CBMs) have stressed the importance of having clarity about the materials and substances in products (Rizos & Bryhn, 2022; Vermunt et al., 2019) and of introducing targeted policies to enhance transparency across supply chains (Kurdve et al., 2019). It has been suggested that policy action in this area can support the replication of CBMs across the EU (Rizos et al., 2015) and create synergies with other policies such as ecodesign and recycled content requirements for new products (Vanner et al., 2014).

The digital product passport (DPP) is a specific digital and policy tool that is expected to revolutionise the way product-related data are collected and shared across supply chains (Jansen et al., 2023). The European Commission's (2022, p.9) proposal for a new Ecodesign for Sustainable Products Regulation (ESPR) describes the DPP as a tool that will 'electronically register, process and share product-related information amongst supply chain businesses, authorities'. This information 'should be easily accessible by scanning a data carrier, such as a watermark or a quick response (QR) code' (European Commission, 2022, p.26). The product-related data sets to be provided by the DPP refer to material composition and origins, chemical substances, carbon footprint, performance as well as to repairability, disassembly, recycling and disposal aspects (European Commission, 2022; Adisorn et al., 2021). Pairing the expanding capacities of digital technologies with circularity principles, the DPP will therefore aim to address the major transparency barrier to circularity discussed above and enable a more sustainable and circular use of products throughout their life cycle (Adisorn et al., 2021; Berger et al., 2022).

Batteries are the first product group for which the use of a DPP will be a legal requirement as of 2027 through the EU Batteries Regulation (European Parliament and Council, 2023). Over the next few years, the EU will require the use of DPPs for additional product groups through the new legal framework on ecodesign. These new legal requirements are the first of their kind at the global level and have piqued the interest of European businesses with a number of DPP initiatives emerging across the EU (Jansen et al., 2022; Damen et

al., 2023). The policy framework on DPPs is still being developed, but there are several key questions about how the landscape of DPP initiatives will evolve, what it will look like, how the DPP will be implemented in practice across different sectors and how confidentiality issues will be addressed (Walden, 2021; Adisorn et al., 2021). This also calls for empirical data and evidence to inform policymakers, businesses and researchers involved in the design and implementation of DPPs (Jensen et al., 2023; Berger et al., 2022).

Focusing on the digital battery passport (referred to throughout the paper as battery passport), this paper explores prospective challenges and opportunities arising from the legal introduction of this digital and policy tool. This study is one of the first to empirically assess the implementation of the battery passport at the EU level, and to our knowledge the first one to use qualitative data from companies across the battery production, use, recycling, and reuse stages of the value chain. Other studies focus on other sectors (i.e. mechatronics, see Jensen et al., 2023) or provide a cross-industry assessment (see Jansen et al., 2023). The paper is produced in the framework of the BATRAW EU-funded project[1] which aims to develop and demonstrate circular approaches for end-of-life electric vehicle (EV) battery packs. During the 48-months of the project, two pilots will be implemented: the first one will apply a semi-automatic battery pack disassembly process to reuse battery components, while the second one will apply a pre-treatment and hydrometallurgical process for the recycling of battery cells and modules.

The remainder of the paper is structured as follows. Section 2 presents the main features of the new EU Batteries Regulation including the battery passport requirements. Section 3 explores the emerging landscape of battery passport examples across the EU and discusses the BATRAW pilot case. This is followed by Section 4 which presents the emerging empirical evidence collected from companies involved in the implementation of the battery passport. Section 5 concludes with key policy messages.

[1] The BATRAW (Recycling of end-of-life battery packs for domestic raw material supply chains and enhanced circular economy) project is funded by the EU Commission's Horizon Europe programme and was launched in 2022.

2. MAIN FEATURES OF THE REVITALISED EU REGULATORY FRAMEWORK FOR BATTERIES

2.1 EU BATTERIES REGULATION

Entering into force in August 2023, the Batteries Regulation aims to revitalise the regulatory framework for batteries in the EU and adapt it to the evolving social, economic and technological conditions in both the EU and globally. Against the background of increasing battery demand due to the continued electrification of transport and energy (Breiter et al., 2022), the new Regulation introduces a range of mandatory requirements for battery design and end-of-life (EoL) handling that aim to enhance the sustainability, circularity and safety of batteries. Table 1 provides an overview of selected key targets and requirements that apply to electric vehicle batteries (EVBs).

The new Regulation establishes EU-wide sustainability requirements for all types of batteries placed on the European market, including EVBs, waste portable batteries, industrial batteries, batteries for light means of transport (LMT), such as electric bikes, and starting, lighting and ignition (SLI) batteries[2]. It thus considerably expands the scope of the 2006 Battery Directive (2006/66/EC), which focused mainly on waste portable batteries and did not cover LMT batteries. In addition, whereas the Battery Directive primarily focused on restricting hazardous substances and improving battery waste management, the Batteries Regulation considers the social and environmental sustainability of all stages of the battery life cycle. Crucially, the new Regulation introduces specific design requirements for batteries which already target EoL management and improved performance throughout the battery life cycle. Battery design and manufacturing will need to comply with higher performance, durability and safety requirements, while minimising the environmental footprint. Some of the key requirements of the new Regulation on sustainability, labelling, EoL management and due diligence are described below.

Sustainability and safety requirements cover a range of different aspects, such as restrictions of hazardous substances and different documentation obligations on carbon footprint and recycled content. Specific recycled content targets are set for different materials present in industrial batteries, SLI batteries, and EVBs. From January 2030, minimum **recycled content targets** are set at 6 % for lithium and nickel, 16 % for cobalt

[2] Thus, batteries placed in stock in the Union by distributors, including retailers, wholesalers and sales divisions of manufacturers, before the date of application of relevant requirements of this Regulation do not need to meet those requirements.

and 85 % for lead, respectively. These mandatory shares will increase over time, to 12 % for lithium, 15 % for nickel, and 26 % for cobalt, and remain at 85 % for lead. Additionally, the Regulation introduces different electrochemical performance and durability requirements for different types of batteries, such as on battery capacity and discharge time. Finally, portable batteries need to be readily removable and replaceable by end users, and there are safety provisions for stationary battery energy storage systems (European Parliament and Council, 2023).

In addition to the sustainability and safety requirements, the Regulation introduces labelling and information rules for economic operators. From 2026 onwards, batteries will need to feature labels including information on, for instance, the manufacturer, the battery capacity, hazardous substances and critical raw materials contained in the battery. From 2027, QR codes need to be established for all batteries to provide access to the labelling information, and to additional information (e.g. declaration of conformity, due diligence report). For EVBs, rechargeable industrial batteries with a capacity greater than 2 kWh and LMT batteries, a carbon footprint declaration will be required for each battery model per manufacturing plant, also accessible via the QR code. These should also provide access to the battery passport (as discussed below) for LMT batteries, industrial batteries with a capacity greater than 2kWh and EVBs. Moreover, to evaluate whether batteries can be used further at end-of-life (EoL), and to facilitate the reuse, repurposing or remanufacturing of the battery, stationary battery energy storage systems, LMT batteries and EVBs will have to include a battery management system (BMS), containing information on the state of health (SOH) and the expected battery lifetime (European Parliament and Council, 2023).

Obligations on EoL management and extended producer responsibility (EPR) are important features of the new Regulation. Battery producers placing a battery on the EU market will be subject to EPR including, for example, financing the separate collection and transport of waste batteries. Producers of several types of batteries will also need to provide take-back and collection systems, and are responsible for making relevant waste prevention and management information available to end users and distributors. To support the establishment of circularity processes for batteries, the Regulation introduces collection targets for different types of batteries. Specifically, producers or EPR organisations acting on their behalf will need to ensure that at least 45 % of waste portable batteries are collected by the end of 2023. This target is then set to increase to 73 % by the end of 2030. For LMT batteries, the collection target will increase from 51 % by the end of 2028 to 61 % by the end of 2031. In addition, the Regulation foresees that all waste batteries should be collected separately by the economic operator or EPR

organisations, thereby prohibiting them from being sent to landfills. The Regulation also introduces minimum recycling efficiencies and levels of recovered materials for all batteries. This is particularly relevant for high-value materials like copper, cobalt, lithium, nickel and lead. For example, the material recovery targets for lithium recycling will start at 50 % by 2027 and rise to 80 % by 2031, while the recycling efficiency target for nickel-cadmium batteries is set at 80 % by the end of 2025 (European Parliament and Council, 2023).

The Batteries Regulation also includes rules on due diligence to minimise environmental and social impacts associated with the battery life cycle. These obligations do not apply to economic operators that had a net turnover of less than EUR 40 million in the financial year preceding the last financial year, and that are not part of a group, consisting of parent and subsidiary undertakings, which, on a consolidated basis, exceeds the limit of EUR 40 million. Economic operators placing batteries on the market will need to set up, implement and verify due diligence policies (by 2025). This implies adopting and (publicly) communicating due diligence policy on raw materials (including cobalt, natural graphite, lithium, nickel and a list of chemical compounds) and associated social and environmental risk categories (such as environment, climate and human health, human rights and community life). The information on responsible sourcing will also need to be provided to the public through the battery passport (see below), as part of an annual battery due diligence report. Moreover, companies need to incorporate due diligence standards based on internationally recognised due diligence instruments and establish a system of supply chain transparency and traceability. For this, documentation will be required on traded raw materials, suppliers, countries of origin of the raw materials and market transactions starting from raw material extraction. Companies placing batteries on the EU internal market also need to conduct risk assessments of adverse impacts in their supply chain, and implement appropriate prevention and mitigation strategies (European Parliament and Council, 2023).

As shown in Table 1, the provisions of the new Regulation will be gradually introduced over the next few years. Since the new framework takes into account the entire battery life cycle, a range of secondary legislation will need to be adopted from 2024 to 2028 to support its implementation.

Table 1. Overview of selected requirements of the Batteries Regulation for electric vehicle batteries (EVBs)

Sustainability and safety requirements	Carbon footprint	2025: Carbon footprint declaration (label) 2026: Carbon footprint performance class requirements 2028: Maximum life cycle carbon footprint threshold (levels to be determined)
	Recycled content	Minimum shares of recovered materials in batteries from 2031: - 16 % cobalt - 85 % lead - 6 % lithium - 6 % nickel From 2036: - 26 % cobalt; - 85 % lead; - 12 % lithium; - 15 % nickel
Labelling and information requirements	Labelling and marking	2025: Symbol for separate collection 2026: Label for general information 2027: QR code giving access to the battery passport
	Information on SOH and expected lifetime	2024: Battery management system to include parameters for determining SOH and expected lifetime
Obligations of economic operators as regards battery due diligence policies	Battery due diligence policies	2025: Economic operators placing batteries on the market need to fulfil due diligence obligations and set up battery due diligence policies
	Economic operator's management system	2025: Adoption and communication of due diligence policy on raw materials and social and environmental risks System of controls and supply chain transparency documenting: - raw material - supplier - country of origin - market transactions from extraction to the immediate supplier - quantities of the raw material present in the battery, etc.
	Risk management obligations	2025: Identification of risks of adverse supply chain impacts and implementation of a response strategy
Management of waste batteries	Collection of EVBs	2025: Producers of EVBs need to take back waste EVBs free of charge from end users Producers of EVBs need to provide take-back and collection systems and deliver collected waste EVBs to treatment facilities
	Targets for recycling	Permitted facilities need to ensure that waste batteries undergo preparation for reuse, repurposing or recycling

	efficiency and recovery of materials	Recyclers need to achieve the minimum recycling efficiency targets below by 2025: - 75 % by average weight of lead-acid batteries - 65 % by average weight of lithium-based batteries - 80 % by average weight of nickel-cadmium batteries - 50 % by average weight of other waste batteries By 2030: - 80 % by average weight of lead-acid batteries - 70 % by average weight of lithium-based batteries Recyclers need to achieve these minimum material recovery targets by 2027: - 90 % for cobalt, copper, lead and nickel - 50 % for lithium By 2031: - 95 % for cobalt, copper, lead and nickel - 80 % for lithium
Battery passport requirements	Battery passport	2027: Establishment of battery passport containing: - Information on battery model - Information specific to the individual battery (Annex XIII) - Different accessibility layers To be accessible through QR code compliant with specified standards
	Technical design and operation	2027: Fully interoperable with other EU DPPs Access free of charge based on access rights

2.1.1 The battery passport

One key novelty of the Batteries Regulation is the introduction of mandatory **digital battery passports** for LMT, industrial batteries with a capacity greater than 2KWh and EVBs. Defined by the Regulation as an 'electronic record', the passport aims to feature information both on the battery model and on the individual battery, with different degrees of visibility. Some data will only need to be available to notified bodies, market surveillance authorities and the Commission, while other information will be publicly accessible or accessible to any natural or legal person with a legitimate interest. Future implementing acts will define who these persons are.

General information on the battery model will be available to the public. This includes information on the manufacturer, the battery category, its capacity and general information on material composition (such as hazardous substances and critical raw materials). Furthermore, the public will be able to access the carbon footprint declaration, information regarding the responsible sourcing of materials (in line with due diligence policies), recycled content and share of renewables. Information on prevention

and management of waste batteries, as specified above, will also be part of the publicly accessible battery passport (European Parliament and Council, 2023).

To facilitate the dismantling of batteries and to support repairers, remanufacturers, second-life operators and recyclers in their operations, the battery passports will also contain more detailed data on battery composition, dismantling (such as the tools required for disassembly) and safety measures, for example. While this information will be available to both the Commission and to persons with legitimate interest, data on individual batteries will only be accessible by the latter. This includes values for performance and durability parameters, SOH, battery status (e.g. 'original', 'reused', 'waste'), and information related to the battery use (e.g. number of charging and discharging cycles, accidents that the battery may have been subject to) (European Parliament and Council, 2023).

The Regulation specifies that QR codes need to be established to access the battery passports, linking to a unique identifier established by the economic operator[3] placing the battery on the market[4]. This economic operator is also responsible for verifying and updating the information in the passport, and for storing the data. The text of the Regulation specifies that the battery passport will cease to exist after the battery is recycled, though no further information about the process is provided in this regard (see also Section 4). When a battery is considered to be waste, the battery passport responsibilities are transferred to the producer or the waste management operator (European Parliament and Council, 2023).

According to the Regulation, all information included in the battery passport needs to be based on open standards, which are yet to be defined. To ensure interoperability, data need to be in an interoperable format and transferrable through an open data exchange network. Interoperability does not only concern battery passports – the Regulation also postulates the need for interoperability with other DPPs that will be put forward in the context of EU law on ecodesign[5].

[3] Article 3 of the Batteries Regulation defines the 'economic operator' as 'the manufacturer, the authorised representative, the importer, the distributor or the fulfilment service provider or any other natural or legal person who is subject to obligations in relation to the manufacture, preparation for reuse, preparation for repurposing, repurposing or remanufacturing of batteries, the making available or the placing of batteries on the market, including online, or the putting of batteries into service in accordance with this Regulation'.

[4] Defined by the Batteries Regulation as 'the first making available of a battery on the Union market', i.e. 'by being supplied by the manufacturer or importer for distribution, consumption or use in the course of a commercial activity, whether in return for payment or free of charge. Thus, batteries placed in stock in the Union by distributors, including retailers, wholesalers and sales divisions of manufacturers, before the date of application of relevant requirements of this Regulation do not need to meet those requirements'.

[5] Replacing the Ecodesign Directive, the new Ecodesign for Sustainable Products Regulation will introduce ecodesign requirements for almost all products placed on the internal market (with the exception of food

3. AN EMERGING LANDSCAPE OF BATTERY PASSPORTS

3.1 BATTERY PASSPORT EXAMPLES ACROSS THE EU

In the wake of the EU legislative developments that will gradually mandate the introduction of DPPs, a range of different initiatives developing proof of concepts or pilot cases of tools that enable transparency and circularity across supply chains have been emerging. So far, most efforts have been focused on the construction sector, automotive and manufacturing industries, textiles, electronic devices, and batteries. Most existing DPP initiatives are a result of private sector activities, either by individual companies or company networks, or receive financial support from EU and national funds. However, up to now only a few DPP schemes have reached the stage of practical implementation (Jansen et al., 2022; Damen et al., 2023). Some examples of relevant initiatives focusing on the battery sector are presented below.

The **Global Battery Alliance (GBA)** is a multi-stakeholder platform aiming to scale up sustainable battery value chains by 2030. The GBA's Battery Passport programme aims to develop a DPP for EVBs to increase transparency and accountability in battery value chains (Global Battery Alliance, 2022). Based on standardised and auditable data, the GBA's battery passport is meant to function as a quality seal for battery sustainability that adheres to reporting rules. Among its various activities, the GBA launched a first proof of concept of a battery passport in January 2023 to demonstrate the practical feasibility of battery passports. In three different pilots (one led by Tesla and two led by Audi), GBA members developed rulebooks for establishing sustainability performance indicators for the battery carbon footprint, as well as due diligence indicators on child labour and human rights (Global Battery Alliance, 2022). Developed via a multi-stakeholder approach involving GBA members from the entire EVB value chain, the proof of concept also included technical battery parameters and tracking, and tracing of material flows. Once completed, the GBA's battery passport will report on progress towards global sustainability goals to support policymaking and development of performance benchmarks, in addition to standard battery passport features like data collection and exchange.

Another notable initiative is the **Battery Pass** project which was launched by an industry-led consortium in 2022. Funded by the German Federal Ministry for Economic Affairs and Climate Action, the Battery Pass aims to advance the implementation of the EU battery

and feed or medicinal products, for instance) to improve their performance. These include requirements on durability, recyclability and environmental footprint. Information requirements specify obligations to communicate on product parameters and facilitate EoL handling of products. DPPs will be part of the latter information requirements. Specific rules for different product groups will be introduced in the coming years through delegated acts.

passport, aligned with the provisions of the new Batteries Regulation (Battery Pass consortium, 2023). The Battery Pass consortium consists of partners from industry and research, involving actors from the entire battery value chain. It is also aligned with other initiatives such as the GBA, CIRPASS, Catena-X, BATRAW and BatWoMan, to integrate different perspectives (Battery Pass consortium, 2023). While its core objective is not to develop a commercial battery passport, the project has set out to create content guidance for the EU battery passport, identify relevant technical standards for the data infrastructure, and develop a software and physical demonstrator. The first content guidance document was released in 2023; it provides detailed information on the reporting requirements of the Batteries Regulation in order to facilitate compliance (Battery Pass consortium, 2023).

In addition to the multi-stakeholder battery passport initiatives, there are now more companies offering battery passport solutions and supply chain traceability services. Using blockchain technology for sharing and storing data on the product's origins, carbon footprint and responsible sourcing, these companies offer compliance services for clients that wish to prepare for the upcoming obligations of the EU Batteries Regulation. Some examples of companies offering such solutions are Minespider, Circulor and iPoint[6].

Several DPP initiatives have been launched in the context of projects funded by the European Commission. Among them, the **CIRPASS**[7] project consists of 31 consortium partners from academia and industry and aims to develop roadmaps for DPP prototypes. These prototypes are focused on three value chains: batteries, electronics and textiles. The overarching goal is to establish shared rules, definitions and principles to conceptualise cross-sectoral DPPs and support a circular economy (DigitalEurope, 2023; EON, 2022). **BatWoMan**[8] focuses on developing sustainable Li-ion battery cell production. In this context, the project partners are demonstrating a battery passport using production data from pilot factories. It aims to validate guidelines and standards defined in related projects (CIRPASS and Battery Pass) (Siska et al., 2023). **BATRAW** and **RECIRCULATE**[9] are further examples of EU-funded projects that conduct focused work on the battery passport. Within these projects, battery passports that are backed by blockchain-secured digital IDs will be implemented and used, with the objective to collect

[6] A more comprehensive list of battery passport examples can be found in CIRPASS consortium (2024).

[7] The CIRPASS (Collaborative Initiative for a Standards-based Digital Product Passport for Stakeholder-Specific Sharing of Product Data for a Circular Economy) project was launched under the European Commission's Digital Europe Programme in 2022.

[8] BatWoMan (Carbon Neutral European Battery Cell Production with Sustainable, Innovative Processes and 3D Electrode Design to Manufacture) is an EU Horizon 2020 project on sustainable battery manufacturing, launched in 2022.

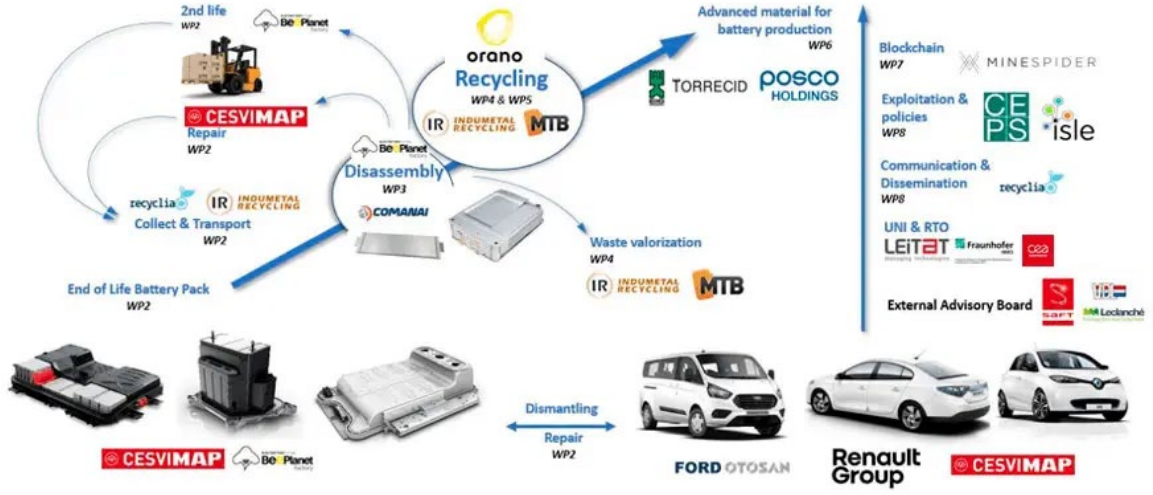
[9] The RECIRCULATE project has received funding from the European Union's Horizon Europe research and innovation programme.

and process data from different battery supply chain actors. More info about the BATRAW case is presented below.

3.2 THE BATRAW CASE

The BATRAW project is a notable example of an EU-funded project on battery sustainability and circularity that seeks to implement on a practical level the requirements of the Batteries Regulation. It aims to develop two pilot systems for sustainable recycling and EoL management of EVBs, as well as for domestic batteries (and battery scraps), to help generate secondary streams of strategically important critical raw materials (Krümpel et al., 2023). To create new procedures for battery repair and reuse, BATRAW focuses on a range of innovations, such as ecodesign guidelines for battery manufacturing and faster conversion of EV battery packs into second-life batteries (see Figure 1).

Figure 1. Overview of the BATRAW project and project partners



Source: BATRAW website.

One of the key deliverables is the demonstration of a battery passport, which was developed by Minespider, a software company and consortium partner. Using blockchain technology for data sharing and QR codes to enable access, the BATRAW battery passport collects key battery data, ESG information and lifecycle requirements based on EU legislation (Krümpel et al., 2023).

The overarching aim of the passport is to enable product and supply chain tracking for batteries, their components, and raw materials, in line with the EU Batteries Regulation. The data concept for the battery passport designed, implemented and demonstrated in the BATRAW project therefore supports participating companies (i.e. project partners) in

what they need to share according to existing and upcoming policies. It contains different layers of transparency depending on user needs and the relevant provisions.

Participants include a range of stakeholders from the EVB value chain, including battery and EV manufacturers, and companies responsible for dismantling, repair, disassembly, recycling, etc. Minespider is responsible for training each company in applying the battery passport to facilitate EVB reuse and recycling processes developed within the project.

Different supply chain actors have different information needs. For example, battery transporters need to know if they have to comply with specific health and safety regulations or whether the materials transported are considered to be waste. A dismantler needs to know how to safely and efficiently handle and dismantle the delivered battery, which tools and precautions are necessary – a damaged battery from an accident involves risk of short-circuit and burning, for example. The more information available, the safer and more efficiently these processes can be designed and performed.

After identifying these different information needs, battery supply chain actors each generate DPPs for the respective materials and products they supply. The battery supply chain consists of a range of individual suppliers providing individual battery components, such as miners, refiners, cell component producers, and cell and module producers, who each have their own respective suppliers. Each of these battery supply chain actors as well as their suppliers (and their suppliers, etc.) can generate a DPP representing their own product, and provide this DPP to their customers when shipping their product. These DPPs can be linked with each other, feeding the relevant data into the DPP of the subsequent product down the value chain, up to the battery passport. This allows all battery components and their own components to be tracked along their respective value chains, demonstrating the chain of custody of each product[10]. Thus, the battery passport can integrate the DPPs of any other product, component or raw material feeding into the battery placed on the EU internal market.

This can include entity certificates such as licences, permits and certifications, and product passport information on, for example, chain of custody, ESG metrics or recycling data. The final battery passport contains the battery status, labelling and information requirements, sustainability and safety requirements, technical documentation and EoL management data. At the second-life and EoL stage, supply chain actors involved in

[10] The battery supply chain can be considered to comprise several 'tiers'. For example, a tier 3 supplier delivers cells and screws alongside the respective DPP to the tier 2 supplier, who adds a case to build a battery module. The tier 2 supplier can then generate a DPP for the module, linking it to the DPP of tier 3. Then, the tier 2 supplier provides both the module and the (linked) DPP to the battery pack manufacturer (tier 1). The battery pack manufacturer can generate a new DPP for the battery pack, and integrate the DPP of the module (which is linked to that of the cells and screws).

collection, remanufacturing, recovery and recycling need to update or generate new DPPs wherever necessary.

To ensure the necessary data transparency while allowing for confidentiality of certain types of data, the battery passport used in the BATRAW project consists of three different layers of data visibility (Krümpel et al., 2023). While the public layer is visible to everyone, the transparency layer is only shared with every subsequent actor in the same supply chain, and the privacy layer can only be accessed by an immediate customer (or other users with the appropriate permission). These different layers can be used to comply with the requirements of the EU Batteries Regulation on data access for different audiences, such as interested persons, the Commission or notified authorities. Concerns about sharing sensitive data as well as other challenges are discussed in more detail in the next section.

4. OPPORTUNITIES AND CHALLENGES

In this section, we identify a set of opportunities and challenges arising from the implementation of battery passports as identified during current pilot cases and applications. The empirical analysis is based on interviews with experts from companies across different parts of the battery value chain that have been involved in implementing battery passports.

4.1 METHODOLOGY

There is limited available empirical evidence on the battery passports since they have only recently emerged in the battery industry landscape. In light of this, we adopted an exploratory research approach for this study. This approach can be used to collect qualitative empirical evidence on under-researched topics (Stebbins, 2001). To develop an in-depth understanding of practical challenges that can emerge across battery supply chains, data have been collected from real-world cases of companies that have been engaged in the design or implementation of battery passports (Rizos & Bryhn, 2022; Milios, 2021. A sample of 16 companies was developed for this assessment through combining the purposive sampling and snowball sampling techniques. Following the former technique, we leveraged the partners involved in the BATRAW project as well as other company experts with specific experience and knowledge in the field (Saunders et al., 2009). In line with the latter technique, we asked the sampled experts for further recommendations for company representatives that could be featured in the analysis (Mack, 2005). As shown in Table 2, the sample includes companies involved in battery production, use, recycling, and reuse as well as companies offering supply chain traceability services.

Table 2. Overview of companies featured in the sample

No.	Activities	Position of interviewees
1	Automobile manufacturer & Developer of battery cells	Manager
2	Developer of batteries	Head of Public Affairs
3	Automobile manufacturer	Head of Sustainability
4	Automobile manufacturer	Innovation Analyst
5	Supplier of battery materials	Manager
6	Dismantler & Provider of automotive parts	Head of Innovation
7	Recycler	Director
8	Recycler	CEO
9	Recycler	Director
10	Developer of recycling equipment	Engineer
11	Developer of second-life applications	Engineer
12	Developer of second-life applications	CEO
13	Provider of traceability services	Manager
14	Provider of traceability services	Head of Business Development
15	Provider of environmental sustainability and innovation services	Project Manager
16	Developer of standards	Head of Public Affairs

Source: Compiled by the authors.

We employed in-depth interviews as the primary method for collecting empirical insights from the sampled company experts. The interviews were organised between August 2022 and April 2023 and lasted about one hour each. During the interviews, the experts were asked to first describe their business model and then provide their perspectives about the EU regulatory framework on batteries including the requirements for the battery passport. The team used a similar approach to other studies exploring barriers to the green transition on the basis of qualitative empirical data for grouping and analysing the collected data (see, for instance, Rizos & Bryhn, 2022; Vermunt et al., 2019; Roberts et al., 2023). The first step involved the preparation of write-ups for all interviews providing detailed accounts of the discussions. The different challenges and opportunities described by the interviewees were then coded with short textual summaries[11] (Saldaña, 2013). The third step involved the transfer of data to an Excel document using the identified codes. The use of codes facilitated the filtering of data and identification of commonalities among the views shared by the experts.

[11] Two examples of such codes used to facilitate the grouping of data were 'uncertain framework for data exchange' and 'unwillingness to share battery-related data'.

4.2 IDENTIFIED OPPORTUNITIES AND IMPLEMENTATION CHALLENGES

4.2.1 Opportunities

Before delving into the implementation challenges, it is important to emphasise that the introduction of the battery passport was generally seen as a positive development by the experts who believed that it has the potential to unlock novel value creation opportunities across battery supply chains. According to the experts having a clear understanding of the operations and impacts across all battery supply chain steps backed by data would help industry actors identify better solutions for reducing emissions across supply chains and the carbon footprint of their operations. The interviewees considered the battery value chain as a very good case to first test the capabilities of this tool for addressing the transparency challenge and to then develop similar requirements for other products groups, based on the insights gained.

Two processes where significant benefits can be attained from the implementation of the battery passport are recycling and second-life applications of batteries. For the recycling process, it was reported that collected lithium-ion batteries often lack a label providing basic information about their manufacturing and content. The experts therefore argued that if properly implemented, the battery passport would provide clarity to recyclers about the content of batteries (e.g. battery chemistry, share of different metals in the battery) and access to key data for determining the battery's SOH and optimal time for recycling. The battery passport was also perceived as an important enabler for second-life applications whose effective implementation require an assessment of the state of the battery and its cells. As shown during implementation of the BATRAW project, while the battery SOH can be approximated through performance tests, having access to key durability parameters (e.g. internal resistance) can facilitate the process significantly.

Opportunities may also arise from the battery passport provisions to make certain battery-related information sets available to the public. Some experts believed that access to carbon footprint information can help increase consumers' awareness of the environmental impacts of batteries and of their consumption choices – which extends to third countries outside the EU – and in the long run promote more eco-conscious decisions, for example, opting for products with recycled content. Achieving full transparency was also seen as an important step in developing a level playing field where actors that adopt more ambitious sustainability approaches are rewarded. Some experts also welcomed the requirement to integrate due diligence aspects (in the form of a report by the economic operator placing the battery on the market) in the battery passport as another contribution to increased transparency. The experts also considered this

obligation as a form of reassurance that some minimum standards on responsible sourcing have been followed by the economic operator[12].

4.2.2 Implementation challenges

Data collection, sharing and reliability

As discussed above, companies view the battery passport as an important tool for boosting circularity across the battery supply chain. However, they also anticipate some challenges with implementation, particularly with regards to data collection and sharing.

With respect to data collection, the company experts suggested that while technical tools for collecting data across supply chains are available, obtaining a full account of all battery-related information required for the battery passport can be practically challenging. As showcased during the BATRAW project pilot case, data on the proportion of different metals in the battery and the various manufacturing steps are among the types of information that are difficult to obtain, given the numerous supply chain actors involved. The project also showed that obtaining values for the parameters determining the state of health of batteries (e.g. internal resistance) can also prove to be a complex task. The experts argued that acquiring data on battery performance and durability in practice would require collaboration between the original battery supplier or producer, the company dismantling or repairing the battery and the user of the battery.

The general reluctance to share data was seen as a potentially important obstacle to collecting all necessary battery passport information. According to the interviewees, companies are accustomed to sharing data if there are non-disclosure agreements in place which provide a reassurance that sensitive data will be handled in a confidential manner. There are also cases where there is a lack of trust between different supply chain actors due to the competitive nature of the market. In some cases, lack of knowledge about the importance of building transparent battery supply chains and the upcoming legal requirements of the Batteries Regulation also contribute to this issue. Interviewees also pointed out that there is often a lack of clarity concerning the access rights to certain types of data, which can create confusion and concerns among companies.

One area of concern referred to the sharing and storing of battery-related data, with experts highlighting the importance of ensuring confidentiality of sensitive data. During some interviews it was suggested that companies should only access certain data based

[12] It should be noted that although the experts were generally positive about integrating due diligence obligations in the battery passport, some expected a higher degree of ambition in the specific requirements. Specifically, it was argued that the requirements for economic operators placing the battery on the market could have extended beyond annually uploading a report on adopted due diligence policies to the battery passport.

on special access rights. According to the experts, it is important to carefully consider the potential risks of providing full access to data to one single company (e.g. a third-party provider) and to take appropriate measures to mitigate them, such as establishing proper security measures and ensuring clarity in the system.

Some experts were also cautious about the interoperability of shared data. Specifically, the interviewees stressed the importance of having standards in place to ensure that battery-related data shared by different actors across global supply chains are provided in a defined format. As the landscape of traceability and battery passport service providers grows, it is also important to achieve interoperability between the systems used by these providers. Given that such standards are not yet in place or extensively used by companies, some company experts considered the timeline for the legal introduction of battery passport requirements (by 2027) to be too ambitious.

Assessing the reliability and validity of collected data may prove to be another challenging area according to the companies. Meeting the objectives of the battery passport will depend on acquiring reliable data (e.g. on carbon footprint) from each actor in the supply chain including those making even a small contribution to battery manufacturing. As noted by companies that place batteries on the market, the battery supply chain involves many companies often from different continents. This makes it difficult in practice to assess the reliability of data collected from their suppliers a challenging endeavour. There were particular concerns about whether actors in the previous steps of the supply chain would document and report their data (especially on carbon footprint) accurately and whether the consolidated data from all actors would be trustworthy enough to make reliable claims about the batteries placed on the market[13].

Other challenges

Further potential challenges beyond strictly data collection and sharing issues were discussed by the company experts. One such challenge referred to the definition of responsibilities for meeting the requirements of the battery passport. To be more specific, one area that is particularly unpredictable is the transfer of battery passport responsibilities after the battery reaches the end of its first life and needs to be repurposed or reused. As noted by some experts, while the text of the Regulation mentions that the responsibility should be transferred to 'the economic operator that has placed that battery on the market or has put it into service', it is uncertain how this will be implemented in practice. Experts also held that although the economic operator is responsible for placing the product on the market and providing the necessary

[13] It should be noted that when it comes to the supply chain transparency obligations, Article 49 of the Batteries Regulation foresees the establishment of a chain of custody or traceability system to support the collection of reliable data (on raw materials, suppliers, origins) (European Parliament and Council, 2023).

information, it is not entirely clear who should be responsible for gathering and updating the required data after that stage. Similar uncertainties exist for the actor and the process for handling and erasing the battery passport data after the battery reaches the end of its life and needs to be recycled.

Challenges may also stem from the carbon footprint requirements of the Batteries Regulation, which will be part of the battery passport. While the methodological guidelines for calculating the carbon footprint of batteries by the European Commission's Joint Research Centre (see Andreasi Bassi et al., 2023) were welcomed by the experts, they also pointed out that they are based on several assumptions of a standard battery supply chain that may not be applicable everywhere. They also argued that even though the Regulation and the guidelines describe the aspects that need to be quantified and define the boundaries of the carbon footprint assessment, it may still be challenging to model all the different aspects in a comparable manner. This was because battery production (including components) and use take place under diverse conditions globally (e.g. in terms of temperature, humidity) with multiple actors involved, thereby complicating the use in such assessments of comparable data. Table 3 below summarises the opportunities and challenges identified during the interviews with experts from the battery value chain.

Table 3. Key opportunities and implementation challenges arising from the battery passport

Opportunities
• Develop a better picture of the carbon footprint of battery manufacturing operations • Test the capabilities of the battery passport tool to then design similar requirements for other product groups • Support battery recycling through better clarity about the batteries' content and state of health • Support second-life applications through having access to key battery durability parameters • Increase consumers' awareness of the environmental impacts of batteries and of their consumption choices • Support more eco-conscious decisions by consumers • Develop a level playing field that rewards actors adopting higher sustainability standards • Provide a form of reassurance about responsible sourcing through due diligence requirements in the battery passport

Challenges
• Practically challenging to collect data from the multitude of companies involved in the various life cycle stages of batteries • General reluctance to share data due to confidentiality concerns and lack of trust between battery supply chain actors • Lack of knowledge about the need for building transparent battery supply chains and the requirements of the upcoming EU Batteries Regulation • Lack of clarity on the access rights to certain types of data • Lack of standards to ensure interoperability of data shared among global supply chain actors • Difficult to assess the reliability and validity of collected data (e.g. on carbon footprint) • Unclear responsibilities for meeting the requirements of the battery passport • Difficult to consolidate all required carbon footprint data and produce comparable results

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

It has long been acknowledged that addressing the transparency challenges that are being perpetuated by the lack of consistent and reliable data about products is a prerequisite for improved circularity and sustainability. Introduced in the context of the revised EU regulatory frameworks for ecodesign and batteries, the DPP is a regulatory and digital tool that aspires to serve as a solution to the above challenges and help unlock opportunities from circular business models. Requiring the collection in a structured way and sharing a range of different product-related information (e.g. on origins and flow of resources, product content, sustainability performance and supply chain due diligence), the DPP is the first legally binding instrument of this kind globally.

In anticipation of the DPP becoming a legal requirement for batteries, a range of initiatives are actively shaping the landscape of digital battery passports. Fostering the development of several best practice examples, key lessons can be drawn from these pilot cases. First and foremost, they stress the significance of the interoperability of product passports, highlighting the need for integration across various systems. Second, effective stakeholder communication emerged as a crucial element to foster trust among supply chain actors. This is pivotal for increasing the willingness to share data and for ultimately enhancing the transparency of battery value chains. The pilot cases that were analysed emphasise the importance of multi-stakeholder approaches, the content guidance development, and alignment between different battery passport initiatives. These insights are not only critical for the effective implementation of battery passports but could also provide inspiration for adopting similar requirements for other product categories in the future.

The empirical analysis of this paper based on in-depth interviews with experts across different parts of the battery value chain provides insights into the opportunities and challenges emerging from the implementation of the battery passport. Acknowledging the need for more traceability and transparency throughout the battery value chain, the experts generally view the battery passport as a tool that can help break down existing information silos. As shown during implementation of the BATRAW project, having access to key streams of information about the content of batteries and their state of health can leverage opportunities for both the recycling of batteries and second-life applications. According to the experts, the passport can also help shed light on the carbon footprint impacts across the various stages of battery manufacturing and thereby support the industry in reducing the impacts of its operations across supply chains. Ultimately the battery passport is seen as a tool that can help create a level playing field for the implementation of CBMs for batteries, introducing requirements for all supply chain actors irrespective of their origins.

While the emerging opportunities from harnessing the capacities of the battery passport were generally recognised during the interviews, the experts went on to describe a number of prospective challenges that need to be addressed for the successful roll-out of this digital tool. As evidenced during existing projects and pilots across the EU, the primary difficulties revolve around the way data are collected and shared among the various battery value chain actors. While the new EU Regulation on batteries will introduce requirements for sharing a range of different data streams (e.g. on battery materials and composition, carbon footprint, performance and state of health), the present pilot cases indicate that the processes of collecting them from the multitude of companies involved in the various life cycle stages of batteries can still be complex on a practical level. Confidentiality concerns and existence of data silos between supply chain actors appear to be important stumbling blocks for this process. Interoperability of data was another point of concern with experts highlighting the need for standards and processes to ensure that the various data points are shared in a defined format that would also allow their effective aggregation. Data reliability is another related challenge with companies, especially from the downstream part of the battery supply chain, expressing doubts about how the collected data (e.g. on carbon footprint) from various companies contributing to battery production will be validated in practice.

Beyond the data collection and sharing issues, interview evidence suggests that there is still a lack of clarity around practical steps in the reuse and recycling processes. For example, it is unclear how the responsibility for handling the batteries will be transferred after the end of the first life stage, or how data will be erased before battery recycling. They also suggested that a higher degree of clarity is needed on the responsibility for collecting data after the stage of entering the market. The experts also called for caution

when it comes to comparing carbon footprint data given the diverse conditions under which battery production and use take place globally.

Drawing on the empirical data and the analysis in this paper the following recommendations are provided:

R1. Provide higher clarity about battery passport-related responsibilities: As showcased by our analysis, there are still ambiguities about certain processes that are required to meet the battery passport requirements. Two such processes concern transferring the battery passport duties (including the obligation to develop a new passport) in cases where the battery is reused or repurposed following its first life and the handling of the passport data before the battery recycling stage. Although the text of the EU Batteries Regulation provides these requirements, further guidance and clarifications about the specific steps for fulfilling them (such as which actor is responsible in each step, how data will be handled) would help avoid confusion by operators. Such guidance could benefit from lessons learned and practical insights from existing pilots (e.g. BATRAW) that develop and implement battery passports.

R2. Support interoperability of battery passport data: As highlighted during the consultations with companies along the battery supply chain, it is important to have standards and processes in place to allow each actor across the global supply chain to structure and share their data in a manner that allows for interoperability. Given that such data-sharing requirements are being introduced for the first time both in the EU and globally through the battery passport, having the appropriate processes and protocols in place to ensure that they are shared in a standardised way will be important for the smooth implementation of this tool.

R3. Create a platform for sharing best practice examples of battery passport initiatives: In light of the proliferation of battery passport initiatives, it will be crucial to consolidate and clearly communicate their findings and outputs. To this end, establishing a centralised online platform connecting existing initiatives may be a useful tool for different actors from the battery value chain. This platform could serve as a knowledge-sharing hub to effectively communicate best practices to actors who will need to meet the upcoming battery passport requirements. This would also help address two of the challenges identified in this analysis: the lack of trust among supply chain actors and the insufficient clarity on specific steps in the implementation process. By creating a centralised space for collaboration and information exchange, stakeholders would gain access to practical examples from ongoing projects that showcase effective battery passport implementation strategies. Such a knowledge-sharing hub could be expanded to cover further sectors and DPP initiatives beyond batteries, given that in the coming years similar requirements will be introduced for additional product groups.

SOURCES

Adisorn, T., Tholen, L. and Götz, T. (2021), Towards a digital product passport fit for contributing to a circular economy, *Energies*, Vol. 14(8), 2289.

Andreasi Bassi, S., Peters, J.F., Candelaresi, D., Valente, A., Ferrara, N., Mathieux, F. and Ardente, F. (2023), Rules for the calculation of the carbon footprint of electric vehicle batteries (CFBEV), Final Draft, Joint Research Centre, Luxembourg: Publications Office of the European Union.

Battery Pass consortium (2023), Battery passport content guidance: Achieving compliance with the EU Battery Regulation and increasing sustainability and circularity, Version 1.0, April 2023.

Berger, K., Schoggl, J.P. and Baumgartner, R.J. (2022), Digital battery passports to enable circular and sustainable value chains: Conceptualization and use cases, *Journal of Cleaner Production*, Vol. 353(15), 131492.

Breiter, A., Horetsky, E., Linder, M. and Rettig, R. (2022), Power spike: How battery makers can respond to surging demand from EVs, McKinsey & Company, accessed 08/08/2023, https://www.mckinsey.com/capabilities/operations/our-insights/power-spike-how-battery-makers-can-respond-to-surging-demand-from-evs.

CIRPASS consortium (2024), D3.1 Annex*: DPP Related Activities (V8), February 2024*, accessed 02/02/2023 at https://cirpassproject.eu/wp-content/uploads/2024/02/CIRPASS-D3.1-Annex-V8.pdf.

Damen, M.A., Stepke-Müller, M., Meyer zum Felde, A., Rubel, H., Turner, J., van Doorne, L. et al. (2023), The EU digital product passport shapes the future of value chains: What it is and how to prepare now, World Business Council for Sustainable Development (WBCSD) and Boston Consulting Group.

DigitalEurope (2023), *CIRPASS Digital Product Passport*, accessed 30/01/2024 at https://www.digitaleurope.org/projects/digital-product-passport/.

EON (2022), *All you need to know about Digital Product Passport initiative, CIRPASS*, accessed 17/08/23 at https://www.eon.xyz/insights/all-you-need-to-know-about-digital-product-passport-initiative-cirpass.

European Commission (2015), Closing the loop – An EU action plan for the circular economy, COM(2015) 614 final, Brussels.

European Commission (2020), A new circular economy action plan: For a cleaner and more competitive Europe, COM(2020) 98 final, Brussels.

European Commission (2022), Proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC, COM(2022) 142 final.

European Parliament and Council (2023), Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste

batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC.

Global Battery Alliance (2022), 2022 Annual Impact Report, Brussels.

Jansen, M., Gerstenberger, B., Bitter-Krahe, J., Berg, H., Sebestyén, J. and Schneider, J. (2022), Current approaches to the digital product passport for a circular economy, Wuppertal Paper no. 198, Wuppertal Institute.

Jansen, M., Meisen, T., Plociennik, C., Berg, H., Pomp, A. and Windholz, W. (2023), Stop guessing in the dark: Identified requirements for Digital Product Passport Systems, *Systems*, Vol. 11(3), 123.

Jensen, S.F., Kristensen, J.H., Adamsen, S., Christensen, A. and Waehrens, B.V. (2023), Digital product passports for a circular economy: Data needs for product life cycle decision-making, *Sustainable Production and Consumption*, Vol. 37, pp. 242-255.

Krümpel, V., Spasovska, P. and Wang, H. (2023), BATRAW D2.3: Report on the design of the concept for sharing data using Minespider's blockchain infrastructure.

Kurdve, M., Zackrisson, M., Johansson, M.I., Ebin, B. and Harlin, U. (2019), Considerations when modelling EV battery circularity systems, *Batteries*, Vol. 5(2), 40.

Mack, N., Woodsong, C., Macqueen, M. K., Guest, G., Namey, M. (2005), *Qualitative research method: A data collector's field guide*, North Carolina: Research Triangle Park.

Milios, L. (2021), Overarching policy framework for product life extension in a circular economy – A bottom-up business perspective, *Environmental Policy and Governance*, Vol. 31(4), pp. 330-346.

Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbers, M. and Ioannou, A. (2015), The circular economy: barriers and opportunities for SMEs, CEPS Working Document No. 412, CEPS, Brussels.

Rizos, V. and Bryhn, J. (2022), Implementation of circular economy approaches in the electrical and electronic equipment (EEE) sector: Barriers, enablers and policy insights, *Journal of Cleaner Production*, Vol. 338, 130617.

Roberts, H., Milios, L., Mont, O., & Dalhammar, C. (2023), Product destruction: Exploring unsustainable production-consumption systems and appropriate policy responses, *Sustainable Production and Consumption*, Vol. 35, pp. 300-312.

Saldaña, J. (2013), *The coding manual for qualitative researchers*, 2nd edn, London: Sage Publications.

Saunders, M., Lewis, P., Thornhill, A. (2009), *Research Methods for Business Students*, 5th edn, Harlow: Pearson Education Limited.

Siska, V., Al-Akrawi, A. and Zackrisson, M. (2023), Building a sustainable battery supply chain with digital battery passports, *IDIMT*.

Stebbins, R. (2001), *Exploratory research in the Social Sciences*, London: SAGE Publications, Inc.

Stepke-Müller, M., Meyer zum Felde, A., Rubel, H., Damen, M.A., Turner, J., van Doorne, L., Sukailo, D., Holtorf, M., and Eggert, F. (2023), *Enabling circularity through transparency: Introducing the EU Digital Product Passport*, BCG and WBCSD.

Vanner, R., Bicket, M., Withana, S., ten Brink, P., Razzini, P., van Dijl, E., Watkins, E., et al. (2014), Scoping study to identify potential circular economy actions, priority sectors, material flows & value chains, Study prepared for the European Commission, DG Environment.

Vermunt, D.A., Negro, S.O., Verweij, P.A., Kuppens, D.V. and Hekkert, M.P. (2019), Exploring barriers to implementing different circular business models, *Journal of Cleaner Production*, Vol. 222, pp. 891-902.

Walden, J., Steinbrecher, A. and Marinkovic, M. (2021), Digital product passports as enabler of the circular economy, *Chemie Ingenieur Technik*, Vol. 95(9), pp. 1717-1727.

ABOUT THE BATRAW PROJECT

BATRAW's main objective is to develop and demonstrate two innovative pilot processes for electric vehicle batteries: i) a semi-automated processes for the handling of the batteries to separate their components, including cells and modules suitable for reuse and ii) a mechanical pre-treatment and hydrometallurgical recycling process to improve the separation of the materials contained in the so-called black mass (a substance composed of non-ferrous metals resulting from the shredding of the batteries). The project will also create a prototype battery from the recovered raw materials and a digital battery passport to capture and communicate key information throughout the battery life-cycle, including the sourcing, processing, (re-)use and recycling of components. As part of the project, eco-design guidelines for the repair and dismantling of batteries, as well as best practices for the safe handling and transport of batteries will be developed. For more information about the project, see: https://batraw.eu

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