Battery Pass

thebatterypass.eu

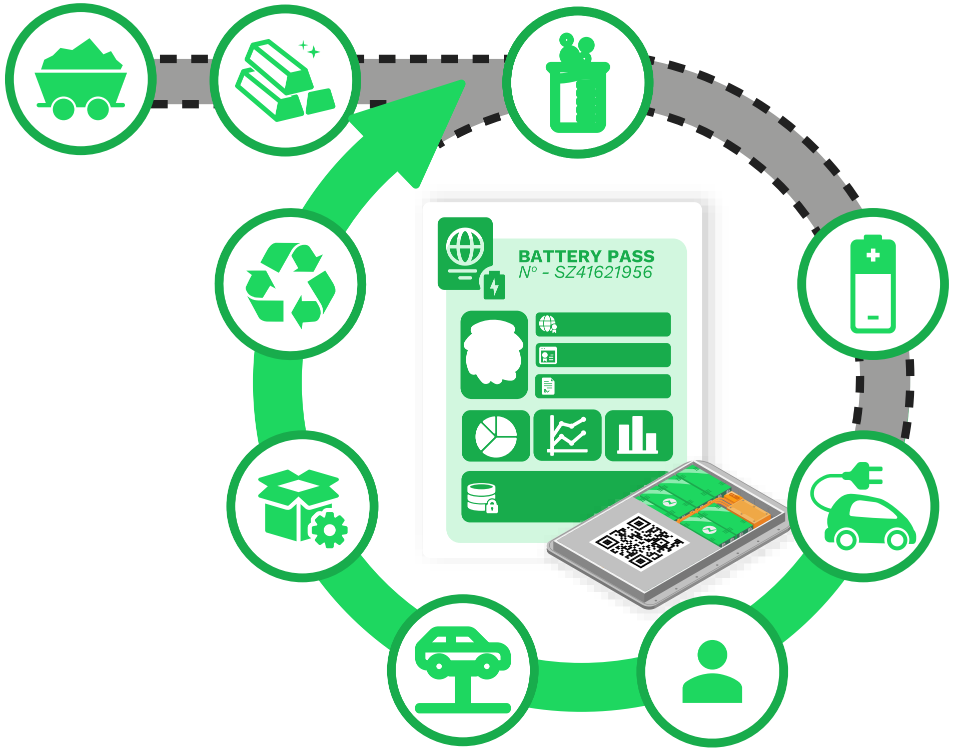
Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The Value of the EU Battery Passport

Version 0.9

An exploratory assessment of economic, environmental and social benefits

April 2024



DISCLAIMER

This document (the "Value Assessment of the Battery Passport, Version 0.9 – An exploratory assessment of economic, environmental and social benefits") is for informational purposes only and is being made available to you by the Battery Pass consortium.

This Document is published by the Battery Pass consortium and contains information that has been or may have been provided by a number of sources. The findings, interpretations and conclusions expressed herein are a result of a collaborative process facilitated and endorsed by the Battery Pass consortium. The Battery Pass consortium partners (the partners as set out on slide 24 of this Document) endorse the overall project approach and findings and the Battery Pass consortium has made efforts to accurately capture stakeholder positions set out by organisations (including supporting partners and further experts), although the results may not necessarily represent the views of all individuals or the organisations they represent. The Battery Pass consortium has not separately verified the information provided from outside sources and cannot take responsibility if any of these statements misrepresent a stakeholder position or if positions evolve over time.

To the extent permitted by law, nothing contained herein shall constitute any representation or warranty and no responsibility or liability is accepted by the Battery Pass consortium as to the accuracy or completeness of any information supplied herein. Recipients of this Document are advised to perform independent verification of information and conduct their own analysis in relation to any of the material set out.

The statements contained herein are made as at the date of the Document. The Battery Pass consortium or any member, employee, counsel, offer, director, representative, agent or affiliate of the Battery Pass consortium does not have any obligation to update or otherwise revise any statements reflecting circumstances arising after the date of this Document.

This Document shall not be treated as tax, regulatory, accounting, legal, investment or any other advice in relation to the recipient of this information and this information should not and cannot be relied upon as such.

If you are in any doubt about the potential purpose to which this communication relates you should consult an authorised person who specialises in advising on business to which it relates.

This document presents the first of two publications from the value assessment and focuses on modelling the benefits of individual use cases

	Slides
Chapter 1: Executive summary	4 - 14
Chapter 2: Introduction	15 - 28
Chapter 3: Methodology	29 - 35
Chapter 4: Benefits	36 - 119
Chapter 5: Challenges and drawbacks	120 - 125
Chapter 6: Outlook and acknowledgements	126 - 129
Annex and sources	130 - 158

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 1: Executive summary

The EU battery passport could create value for business, authorities and consumers – but to fully leverage its potential, interventions beyond regulation are needed

- **The battery passport as per the Battery Regulation promises to enable several direct use cases, in particular for circular management of batteries downstream of manufacturing** – additional specifications of voluntary data attributes, implementation of upstream traceability, integration in regulated downstream processes and systems, and aggregation of data attributes from different battery passports could expand value creation by enabling additional potential use cases
- **We assessed the benefits of the battery passport along twelve use cases qualitatively with a deep dive including an initial quantitative assessment on three selected use cases** to understand where and how battery passport data could lead to more efficient operations, product differentiation, and a digital and green market
- **Companies along the battery value chain should consider battery passports as a strategic opportunity to generate value.** We find that:
  - Information availability through the battery passport could **increase the credibility and reliability of supply chain data** and green claims for product differentiation, **enable informed purchasing decisions,** ease servicing, improve used battery transport risk assessment, **streamline the trade of used batteries,** enable industry benchmarking and an accurate market overview
  - Performance data could simplify the **residual value determination** and **reduce procurement including technical testing costs for independent operators by ~ 2-10%**
  - Composition and dismantling information could make the **recycling process more efficient** and **reduce the costs for pre-processing and subsequent treatment in recycling by ~ 10-20%**
- **The regulator should facilitate the realisation of this value by creating conducive conditions and by offering targeted support to companies struggling with capacity.** To fully materialise the value creation potential of the battery passport, we recommend:
  - The battery passport should be **integrated wherever possible into existing regulatory procedures and systems,** e.g. Green Public Procurement. Additionally, reported battery passport information should be leveraged for the design of upcoming policies and policy changes
  - **Additional data attributes should be allowed** in a separate "beyond regulation" battery passport section to enable the battery passport being used as a B2B tool
  - The battery passport **should be used in vehicle de-registration and export procedures,** which could **lead to more secondary active materials becoming available, potentially fulfilling ~ 5-20%** of material demand for projected European passenger vehicles in 2045
- **Consumers could benefit from battery passport information through informed purchasing decisions and residual value determination improvements.** The benefits of the battery passport and data need to be communicated effectively to motivate consumer engagement

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The battery passport, a breakthrough EU innovation, is actively supported by the Battery Pass consortium, which aims to create resources facilitating its implementation

The **battery passport** is a breakthrough EU innovation to digitally support sustainable, circular, high-performing batteries

- A **digital product passport** (DPP) is a novel concept **making available comprehensive life cycle information** of a physical product in digital format introduced by the European Union as part of its broader regulatory ambition towards sustainability and a digitalised economy
- The battery passport will be **required from February 2027 onwards** by the EU Battery Regulation, encompassing around 90 data attributes from seven content clusters for **electric vehicle (EV), light means of transport (LMT) and industrial batteries with a capacity > 2kWh**
- Next to the European Union, **similar** (regulatory) **efforts** on the introduction of a digital product or battery passport are **ongoing globally**

The **Battery Pass consortium** set out to create resources that support the implementation of the EU battery passport by industry

CONSORTIUM LEAD

SYSTEMIQ

CONSORTIUM PARTNERS

acatech, Audi, BASF, BMW GROUP, Circulor, FIWARE Foundation, Fraunhofer IPK, TWAICE, umicore, VDE Renewables*

*under subcontract

- The "Battery Pass" is a consortium of 11 partners from industry, science, technology and beyond, co-funded by BMWK **aiming to advance the implementation of the EU battery passport** and therefore also collaborating with other major initiatives in the DPP space (e.g. CIRPASS, GBA, Catena-X)
- Initiated and led by the systems change company Systemiq, the Battery Pass works to create **industry guidance** on content requirements, the **technical reference framework** for DPP, a **software demonstrator**, and a **value assessment**
- This document presents the first of two publications addressing the value assessment and focuses on **modelling the benefits of individual use cases qualitatively and quantitatively** (illustrative)

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The value assessment represents a collaborative effort of the Battery Pass consortium that covers a comprehensive scope and is validated by external stakeholders

Scope of the assessment and methodological process

Requirements			Value			Impact dimensions				
Mandatory requirements[1]	+	Voluntary additions	Benefits	vs.	Challenges and drawbacks	Economic (e.g. cost efficiency)	+	Environmental (e.g. GHG emissions)	+	Social (e.g. health and safety)

Battery Pass consortium partner perspective

- **15** Consortium group meetings
- **6** Sub-working groups

External battery industry perspective

- **>30** Expert interviews
- **2** Public consultations

- The value assessment was led by Systemiq in a **collaborative effort with the Battery Pass consortium and validated by external stakeholders** to incorporate the perspective of the entire battery value chain
- The scope includes **mandatory requirements as well as voluntary additions** and differentiates between benefits and drawbacks in three impact dimensions (economic, environmental and social)
- While all battery categories requiring a passport are included in the overall assessment, the **deep dives focus on EV batteries**, and a **separate analysis highlights differences for industrial batteries**

1. As per the EU Battery Regulation

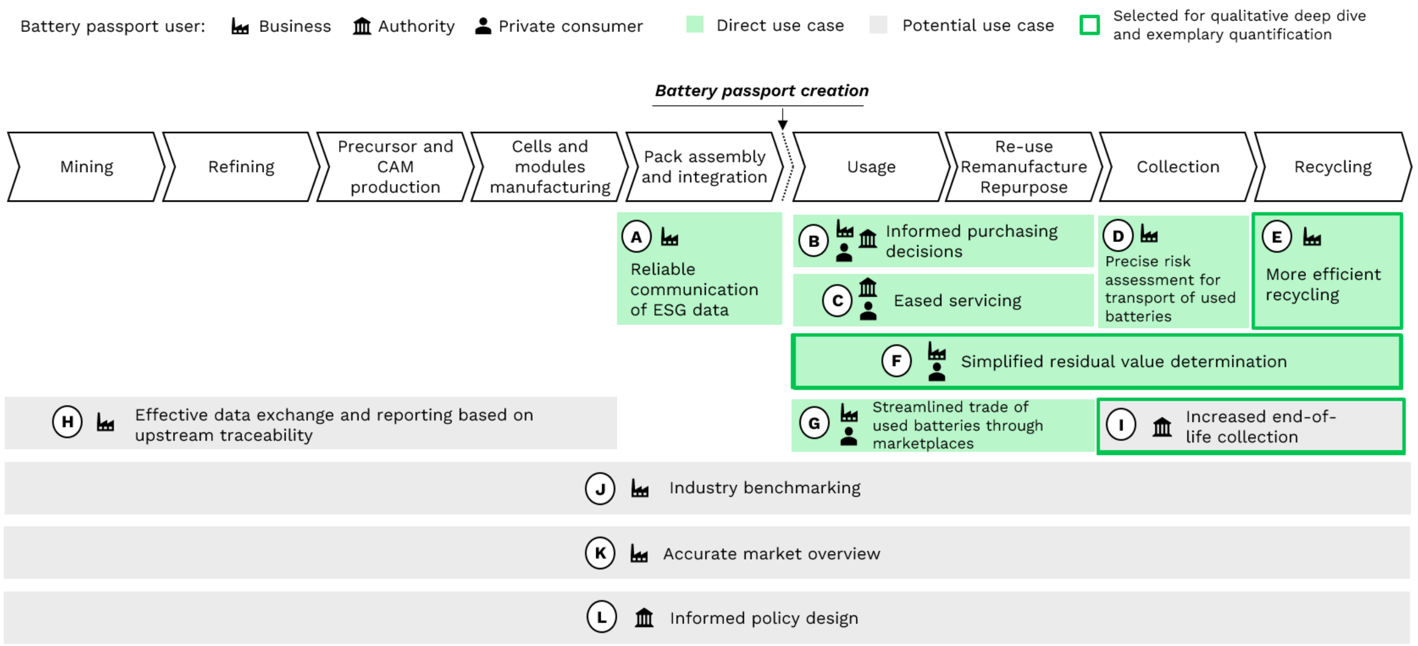
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Benefits of the battery passport will arise throughout the battery value chain, though particularly during a battery's service life

Overview of benefits and use cases

- The battery passport provides **added value** compared to the general reporting requirements[1] from the Battery Regulation by **collecting data in a digital format and making it securely accessible** to users with the respective access rights
- So called "**use cases**" describe **processes which could be improved by using the battery passport** and are **identified to understand** which **economic, environmental and social benefits** arise by using the passport
- We identified and qualitatively described **twelve battery passport use cases** along the value chain, of which we **assessed three in further detail** qualitatively and quantitatively
  - Seven "**direct**" use cases result from **mandatory data attributes** required by the EU Battery Regulation in combination with their respective access rights
  - Five "**potential**" use cases could be enabled provided certain **conditions** are in place which would go **beyond current regulatory requirements**

Overview of battery passport use cases along the value chain



1. Reporting requirements independent from the battery passport

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Seven direct use cases are enabled by mandatory data attributes and their respective access rights - they unlock value along the downstream value chain

Direct use cases[1]

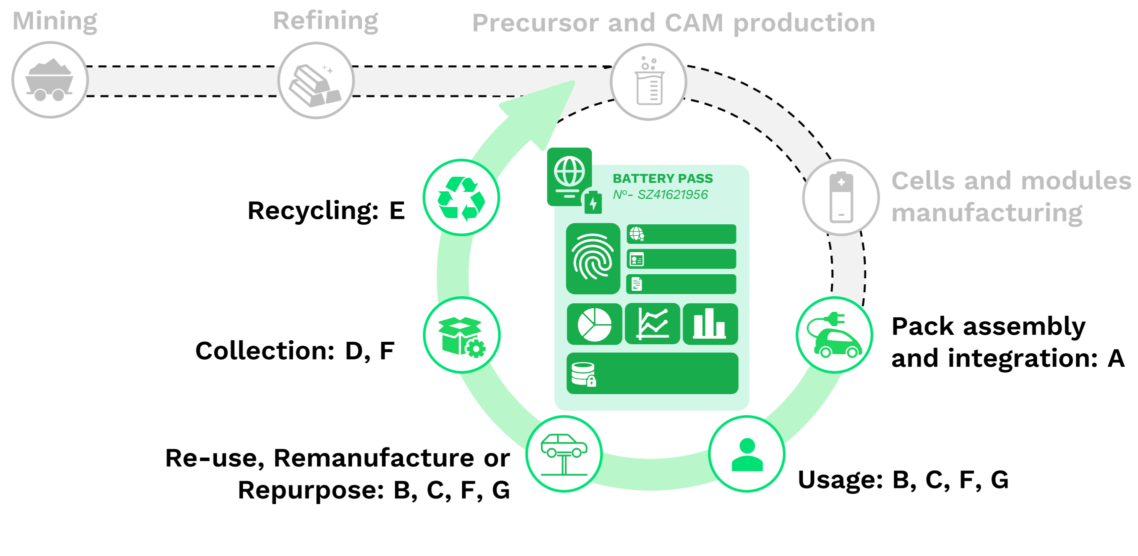
Mandatory data attributes + respective access rights

Use case	Benefit: Economic	Benefit: Environmental	Benefit: Social
(A) Reliable communication of ESG data	Middle	Low	Low
(B) Informed purchasing decisions	Middle	Middle	Low
(C) Eased servicing	Middle	Middle	Low
(D) Precise risk assessment for transport of used batteries	Middle	Low	Low
(E) More efficient recycling processes	High	Low	Middle
(F) Simplified residual value determination	High	Middle	No
(G) Streamlined trade of used and waste batteries through marketplaces	Middle	Low	No

Benefit: Economic, Environmental, Social

Level of benefit: No, Low, Middle, High

Distribution of direct use cases along the value chain



Direct value add along several dimensions (environmental, social and economic)

1. Please refer to the slides 46-79 for an analysis of direct use cases

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Two deep dives indicate that the battery passport could lead to significant cost savings for recyclers and second-life operators as well as substantial environmental impact reduction

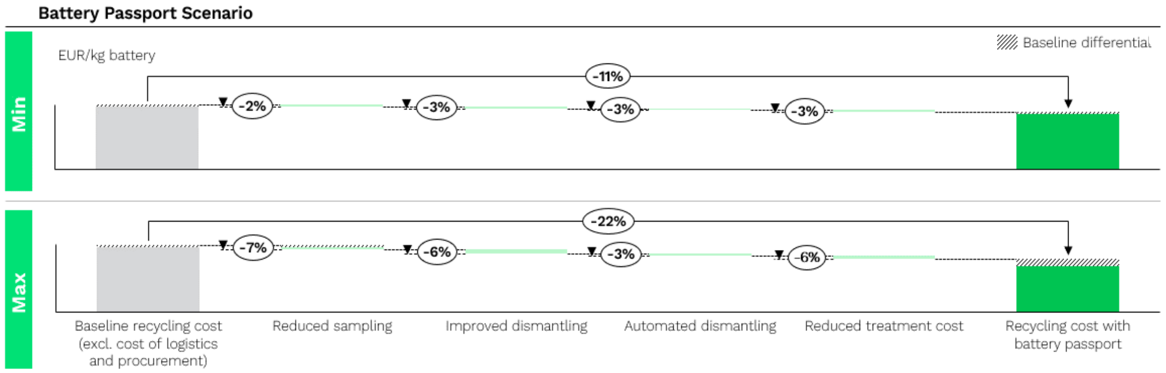
Deep dive use case E: More efficient recycling processes

- Data available from the battery passport could **enable recycling process improvements** leading to economic (pre-processing and recycling cost reduction), environmental (secondary material increase, CO_2 reduction) and social (health and safety improvements) benefits
- An initial quantification[1] of potential improvements of the mechanical-hydrometallurgical process route, indicates that composition and dismantling data might **decrease recycling costs for pre-processing and treatment by ~ 10-20%** based on current generic recycling cost estimations for NMC batteries

Recycling costs reduction through the battery passport[1]

Micro perspective: Example High-Nickel NMC (622) EV Battery; generic mechanical-hydrometallurgical recycling cost (excl. cost of logistics and procurement)

Note that LFP battery recycling has different unit economics – however, the general pre-processing cost reduction levers could apply similarly.



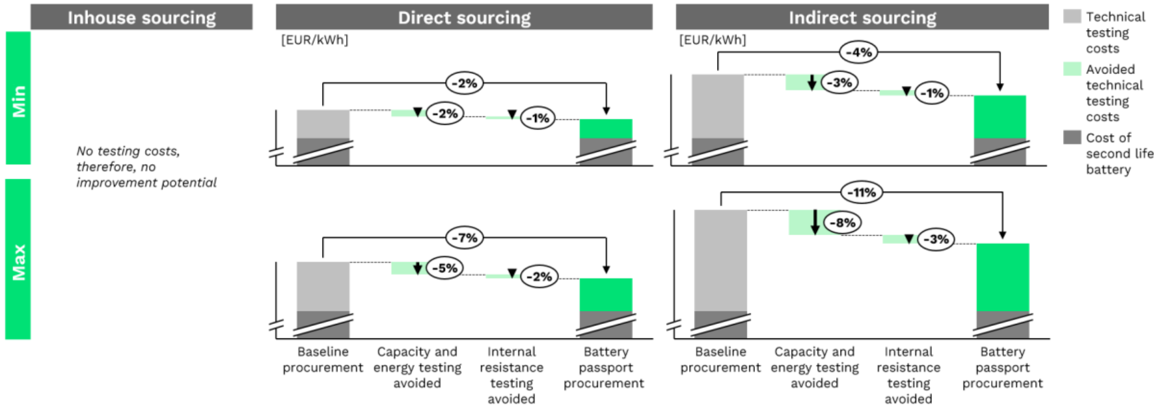
- Additionally recovered active materials **could meet up to 25% of the difference between the technically possible maximum recovery rates and recovery rate targets** from the battery regulation[1]

Deep dive use case F: Simplified residual value determination

- Historic performance and durability information available through the battery passport could **improve the residual value determination process** by reducing the need for technical tests and improving the accuracy of the assessment. Thereby, decisions between second-life and recycling could be facilitated
- An initial quantification[2], of the residual value determination process for three different battery sourcing scenarios shows that through avoiding technical tests, **~2-10% of the procurement including technical testing costs could be reduced** for independent second-life operators

Second-life procurement and technical testing costs reduction through the battery passport[2]

Micro perspective: Baseline procurement incl. technical testing costs for three different battery sourcing scenarios and reduction enabled by the battery passport



- Due to the decrease of costs, we estimate a proportional increase in batteries going into second-life, which **could fulfil ~ 6-20% of the demand for stationary battery energy storage** in Europe[2]

1. Please refer to the deep dive on slides 57-68 and the technical annex on slides 132-134 for more information on the modelling and assumptions
2. Please refer to the deep dive on slides 69-79 and the technical annex on slides 135-137 for more information on the modelling and assumptions

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Conditions beyond regulatory requirements (upstream traceability, integration into official downstream processes and aggregated data) could enable five potential use cases

Potential use cases[1]

Conditions required beyond regulatory requirements	Use case	Benefit: Economic	Benefit: Environmental	Benefit: Social
Application of traceability systems for data collection The Battery Regulation and passport data requirements increase the need for reliable and credible data in upstream value chains. This could be enabled by gathering the data via traceability systems which, when complementing battery passport solutions, could unlock another use case through optimising data processing and use.	**(H) Efficient data exchange and reporting based on upstream traceability**	Middle	Low	Low
Integration into official downstream processes To ensure battery collection, additional information on the downstream status as well as integration into official processes such as export control are needed. This would unlock another use case.	**(I) Increased end-of-life collection**	High	High	Middle
Aggregation of data from different passports Aggregation of data from different battery passports, solved through an EU Commission-provided infrastructure or managed by specialised service providers, could provide additional information on market or organisation level and thereby unlock further use cases.	**(J) Industry benchmarking**	High	Middle	Low
	(K) Accurate market overview	Middle	Low	No
	(L) Informed policy design	Middle	High	Low

Benefit: Economic, Environmental, Social

Level of benefit: No, Low, Middle, High

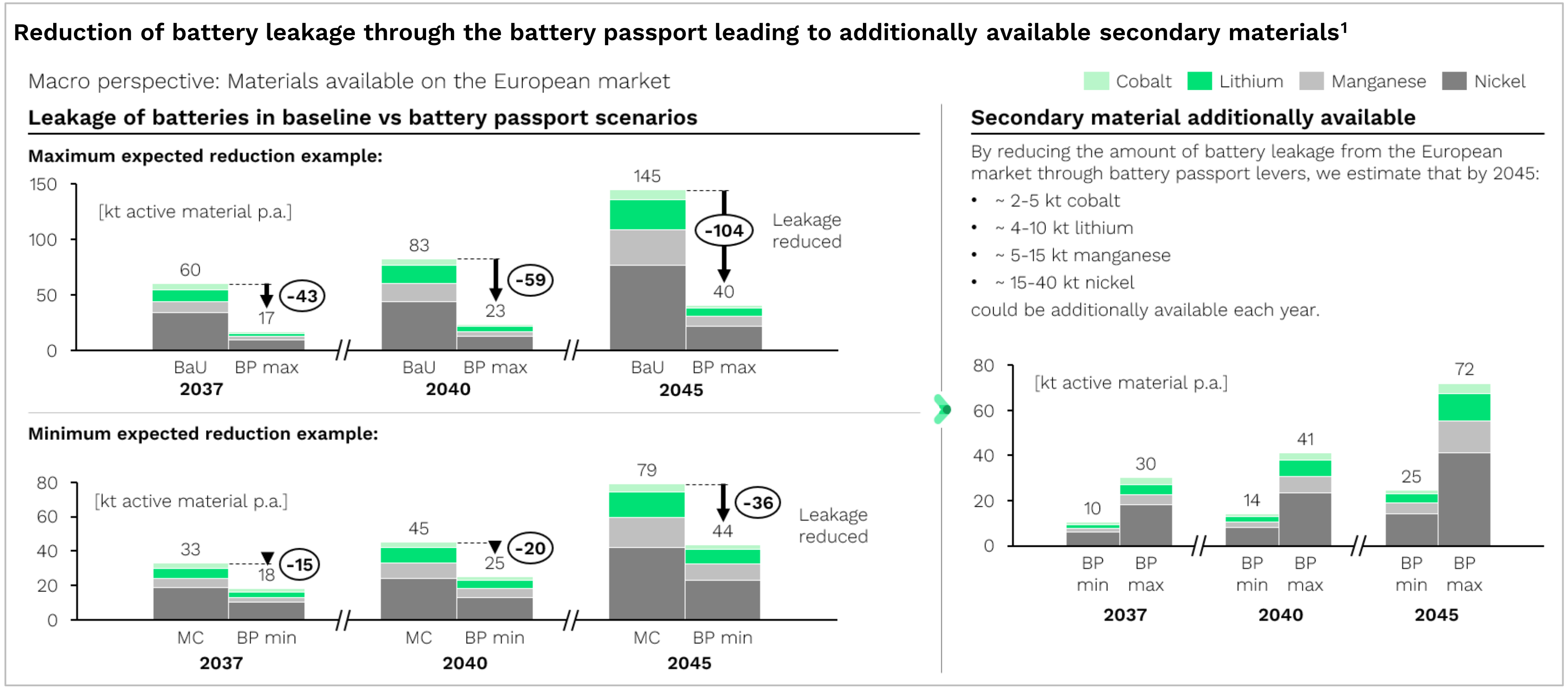
1. Please refer to the slides 80-109 for an analysis of potential use cases

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The third deep dive highlights the potential for a substantial macroeconomic benefit of the passport by leading to more secondary material available on the European market

Deep dive use case I: Increased end-of-life collection

- Integration of the battery passport into regulated downstream processes with additional data attributes could **support authorities in identifying and thereby reducing illegal exports and illegal treatment**. This would result in benefits such as increased supply security, recycling revenue increase, health and safety, as well as reduced emissions
- An initial quantification[1] shows that a reduction of battery leakage through the battery passport could lead to **more secondary active materials available** that could **fulfil ~ 5-20% of projected European passenger EV demand** in 2045



- Moreover, the additional availability of secondary active material in the EU market could **increase recycling revenue by ~ 5-15%** and **cause a ~ 2-10% reduction of carbon emissions** associated with raw material extraction of active materials required to meet EV battery demand

1. Please refer to the deep dive on slides 90-100 and the technical annex on slides 138-140 for more information on the modelling and assumptions

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

A separate analysis for industrial batteries shows the applicability of all use cases while highlighting differences due to technological, usage, and business characteristics

The added value is strongly affected by industrial batteries' different applications and characteristics

- **Differing characteristics and use patterns** of industrial applications (e.g. energy storage, electric logistics solutions, heavy duty) **as well as correspondingly varying business processes reduce benefits**
- The **broad range of technologies/chemistries** (Li-ion, Pb-acid, Ni-based or redox-flow) used in industrial batteries introduces specific characteristics that **distinguish the value assessment** for subgroups of industrial batteries
- Benefits associated with detailed **dynamic battery passport data** are **not applicable** to industrial batteries **without battery management system/ connectivity**

General use case applicability to industrial batteries[1]

Legend: ✓ Equally applicable – Less applicable x Not applicable

Use Case	Applicability
(A) Reliable communication of ESG data	✓ All industrial batteries
(B) Informed purchasing decisions	✓ Industrial batteries with BMS – Industrial batteries without BMS
(C) Eased servicing	– All industrial batteries
(D) Precise risk assessment for transport of used/waste batteries	✓ Industrial batteries with BMS – Industrial batteries without BMS x Industrial batteries with external storage
(E) More efficient recycling processes	✓ Industrial batteries with Li-Ion and emerging chemistries – Industrial batteries except Li-Ion and emerging chemistries
(F) Simplified residual value determination	– All industrial batteries
(G) Streamlined trade of used/waste batteries through marketplaces	✓ All industrial batteries
(H) Efficient data exchange and reporting based on upstream traceability	✓ All industrial batteries
(I) Increased end-of-life collection	– All industrial batteries
(J) Industry benchmarking	✓ Industrial batteries with BMS – Industrial batteries without BMS
(K) Accurate market overview	✓ Industrial batteries with BMS – Industrial batteries without BMS
(L) Informed policy design	✓ All industrial batteries

1. Please refer to the analysis on slides 110-119 and the annex on slides 141-153 for more detailed information

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

We acknowledge that the battery passport also presents challenges that could lead to drawbacks diminishing the overall value when unmitigated, which we will assess further

Challenges and drawbacks[1]

- While unmitigated challenges may decrease the passport's overall value, the **benefits** derived from above explained use cases are **expected to outweigh the drawbacks**
- **Technical and battery passport system challenges** are expected to mostly **affect** the **passport issuer** and require industry collaboration, investment in emerging technology and authority support in enforcing standards
- **Capability and resource challenges** are estimated to mainly **impact SMEs** and necessitate early intra-organisational alignment, harmonised requirements and financial support

Challenges

Difficulties or obstacles that **stakeholders are facing when creating, maintaining or using the battery passport**

Reinforcing

1 Technical and battery passport system

- Connected to required technical design of the battery passport
- Relevance varies based on stakeholder's role in the system

2 Capabilities and resources

- Linked to stakeholder's individual abilities
- Relevance varies based on stakeholder's size[1] and capabilities

Outlook The Battery Pass consortium will **continue the value assessment** by assessing challenges and drawbacks in more detail, considering systemic perspectives and quantifying cumulative benefits.

1. Please refer to slides 120-125 for details on challenges and drawbacks
2. Only applicable for businesses

Chapter 2: Introduction

- Battery Passport
- Battery Pass consortium

A digital product passport (DPP) is a novel concept making available comprehensive life cycle information of a physical product in digital format

Core elements and functioning of the battery passport system

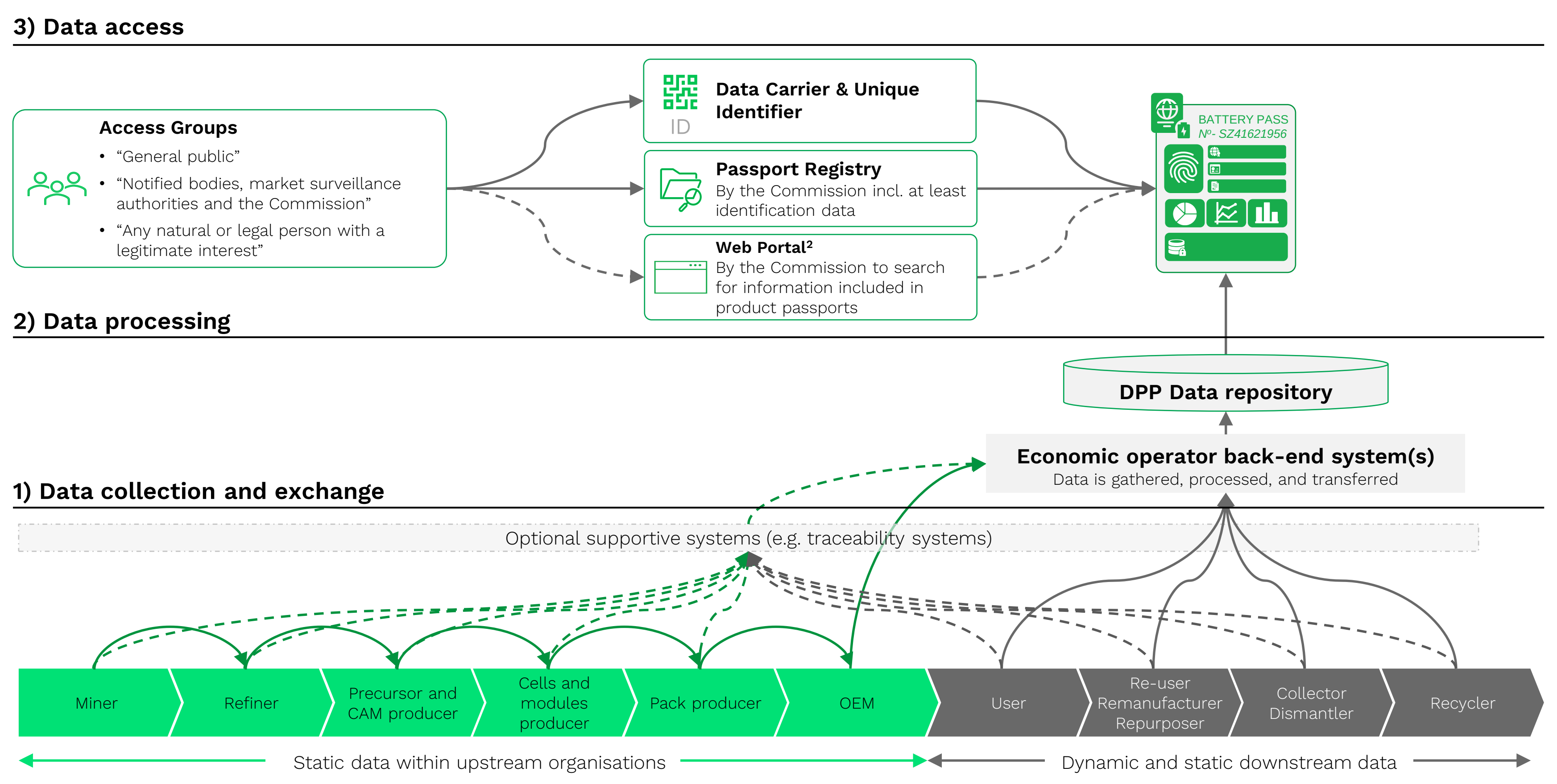
DPP definition

The Council of the European Union[1] defines a digital product passport (DPP) as:

> *"A set of data specific to a product that includes the information specified […] and that is accessible via electronic means through a data carrier.[1]"*

DPP functioning

1) Data is collected within organisations and exchanged between value chain players
2) Data is gathered, processed and transferred to the product passport by the economic operator
3) Data is accessed from product passport by pre-defined groups based on respective access rights



1. Council of the European Union (2023)
2. The Web Portal is not mentioned in the EU Battery Regulation, only in the ESPR. The Web Portal's functioning is not described in detail. Its set-up and management lie within the responsibility of the Commission.

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The European Union is introducing DPPs as part of its broader regulatory ambition towards sustainability with the first one being required for batteries from 2027

NOT EXHAUSTIVE[1]

European Green Deal

Comprehensive plan to make the EU climate-neutral by 2050, safeguard biodiversity, establish a circular economy and eliminate pollution, while boosting the competitiveness of the European industry and ensuring a just transition for the regions and workers affected

Circular Economy Action Plan

Initiative promoting the sustainable use of resources, especially in resource-intensive sectors with high environmental impact

Ecodesign for Sustainable Product Regulation (Agreement)

- Released in Dec 2023, as central part to the Commission's strategy for eco-friendly and circular products
- Extends beyond current Ecodesign Directive, which exclusively addresses energy-related products
- Aims to promote environmental sustainability across a broader range of

Introduces **digital product passports** as a general concept

Battery Regulation (Entered into force)

- Initially proposed in 2020 complementing the Strategic Action Plan for Batteries
- Entered into force in Aug 2023 replacing the EU Battery Directive
- Provides a legal framework aiming to promote sustainability, circularity, safety and transparency

Mandates a **battery passport** for all EV, LMT, and industrial (>2kWh) batteries starting Feb 2027

Focus of this document

End-of-Life Vehicle Regulation (Proposal)

- Proposed in Jul 2023, as result of the review of the End-of-life Vehicle Directive
- Will replace the End-of-life Vehicle Directive as well as the Type-approval Directive
- Governs the entire vehicle life cycle, from design to end-of-life treatment

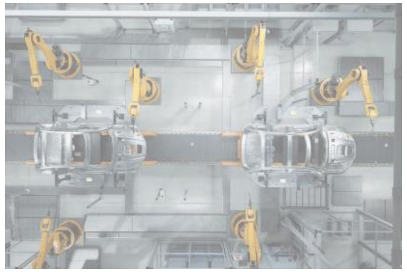
Mandates a **circularity vehicle passport** starting 7 years after entry into force of the regulation

1. There are other legislations including product passports e.g., construction products or toy directive

Sources: European Commission (2019); European Commission (2020); Council of the European Union (2023); European Commission (2023a); European Commission (2023b)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Via the EU battery passport, the Commission aims to support the overarching objectives of the Battery Regulation by promoting sustainability and circularity through transparency

Stakeholder group		Battery passport objective
Business		"It should **provide** remanufacturers, second-life operators and recyclers with up-to-date **information for the handling of batteries** and specific actors with tailored information such as on the state of health of batteries & **allow economic operators** to gather and re-use in a more efficient way the information and data on individual batteries placed on the market and **to make better informed choices in their planning activities**"
Private Consumer		"The battery passport should **provide the public with information about batteries placed on the market and their sustainability requirements**. That information would **enable end-users to make informed decisions** when buying and discarding batteries."
Authorities		"It should be possible for the battery passport to **support market surveillance authorities** in carrying out their tasks under this Regulation (…) & (…) **help facilitate and streamline the monitoring and enforcement of the regulation** carried out by EU and Member State authorities."

License free pictures from pixabay and pexels

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The scope of information to be made available via the battery passport is extensive with up to 90 data attributes covering seven content clusters

NOT EXHAUSTIVE

Data categories for the battery passport (select data attributes shown below)[1]

Battery Pass

Battery ID: 0101010
Battery passport ID: 1111010
Responsible economic operator

General information

- Manufacturing info (identity, place, date)
- Battery category
- Battery weight
- Battery status

Labels and certifications

- Symbols and labels
- Meaning of labels & symbols
- Declaration of conformity
- Compliance of test results

Carbon footprint

- Carbon footprint
- Weblink to CF study
- CF performance class

Supply chain due diligence

- Due diligence report

Materials and composition

- Hazardous substances
- Battery chemistry
- Critical raw materials
- Materials used in cathode, anode, electrolyte

Circularity & resource efficiency

- Recycled content shares
- Manuals for removal, disassembly, dismantling
- Component part numbers & spare parts information
- Safety measures/instructions

Performance & durability

- Capacity, energy, power, SoH
- Expected lifetime
- Negative events

1. For a full overview of data attributes please refer to the Data Attribute Long List: https://thebatterypass.eu/resources/

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The introduction of the battery passport affects the organisations across the battery ecosystem differently

NOT EXHAUSTIVE[1]

Responsible economic operator
Collect data[1] from the value chain and on own operations, process the information and issue the battery passport while ensuring compliance with its requirements

Battery value chain participants
Gather and provide accurate information to the responsible economic operator

Technology provider
Develop and maintain the technological infrastructure required for the battery passport by ensuring security and interoperability

Audit companies
Verify accuracy of provided information, validate adherence to the regulation and offer independent certification services

National market surveillance authorities
Ensure enforcement of battery passport requirements, monitor compliance and take appropriate action against non-compliance

European Commission
Oversee and regulate the implementation of the battery passport by providing a thorough legal framework and supporting industry in overcoming challenges

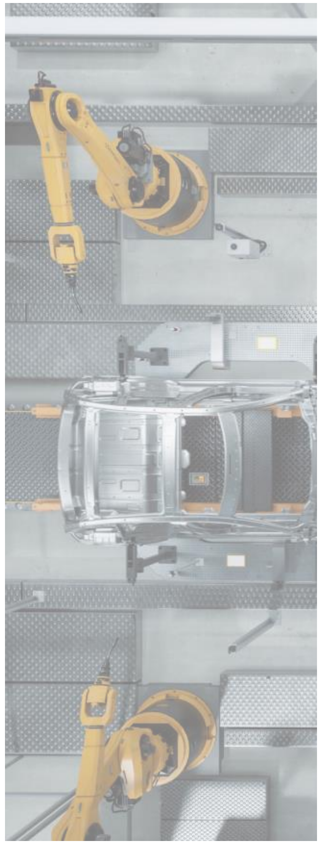
Standardisation organisations
Establish and update standards for battery passports to ensure consistency and compatibility across the industry

1. Or authorise another entity to collect data
Note: Verify accuracy of provided information, validate adherence to the regulation and offer independent certification services

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The industry expects the battery passport to enable efficient operations, product differentiation and a digital and green market development

To create value for businesses, the battery passport should enable:



Efficient operations

- **Value chain optimisation**: Optimise supply chains by incorporating data into sourcing and strategic processes
- **Process optimisation**: Leverage data to increase speed and automate processes
- **Decision-making and planning**: Enhance design, production, re-use, and recycling decisions with battery life cycle insights and market intelligence

Product differentiation

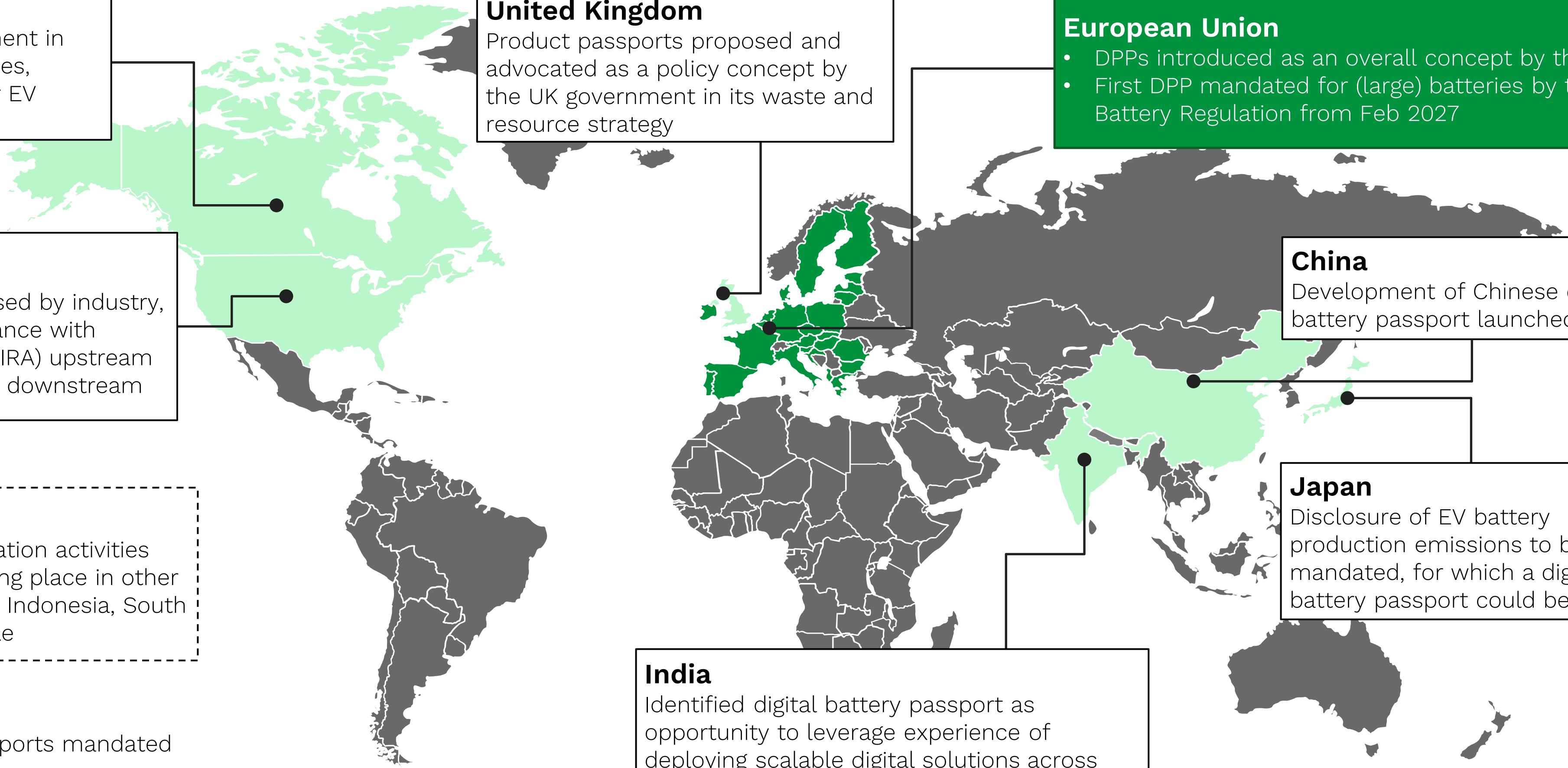
- **Transparency**: Report environmental and social responsibility to customers and end-consumers
- **Value proposition**: Emphasise product performance attributes for market differentiation and comparability
- **Product management**: Ensure quality control and safety through comprehensive product specifications and performance records

Digital and green market

- **Value chain digitalisation**: Advance data economy and ecosystems growth to maximise the value of data and systems
- **Sustainable business models**: Enable multiple life uses through battery data, enhance services and develop/optimise circular business models
- **Level playing field**: Establish a fair and equitable environment to support a green EU industry and enhance resource resilience in value chains

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Next to the European Union, similar efforts on the introduction of a digital product / battery passport are ongoing globally



Canada
Involvement of government in battery passport initiatives, considering passport for EV batteries

United Kingdom
Product passports proposed and advocated as a policy concept by the UK government in its waste and resource strategy

European Union
- DPPs introduced as an overall concept by the ESPR
- First DPP mandated for (large) batteries by the Battery Regulation from Feb 2027

United States
Battery passport discussed by industry, e.g. for ensuring compliance with Inflation Reduction Act (IRA) upstream and optimising recycling downstream

China
Development of Chinese digital battery passport launched

Others
International standardisation activities regarding DPPs also taking place in other countries such as Brazil, Indonesia, South Korea, Australia and Chile

Japan
Disclosure of EV battery production emissions to be mandated, for which a digital battery passport could be used

India
Identified digital battery passport as opportunity to leverage experience of deploying scalable digital solutions across stakeholders in the battery value chain

Digital product passports mandated

Efforts regarding digital product passports ongoing

Sources: European Commission (2022a); Balakrishnan (2022); World Economic Forum (2023); Garg (2023); King et al. (2023); GPQI (2023); Circular Australia (2023

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Chapter 2: Introduction

- Battery Passport
- Battery Pass consortium

The Battery Pass is a consortium of 11 partners from industry, science, technology and beyond, co-funded by BMWK aiming to provide guidance on the EU battery passport

Key facts on the Battery Pass consortium

- Evolved from the Circular Economy Initiative Germany
- 11 partners from industry, science, technology and beyond
- Co-funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) with EUR 8.2 mn
- Aiming to advance the implementation of and provide guidance on the EU battery passport
- 3-year timeframe from April 2022 to April 2025
- Five work packages include:
  - Project coordination and stakeholder engagement
  - Guidance on content requirements
  - Guidance on technical battery passport system
  - Development of a software and physical demonstrator
  - Value assessment of individual use cases and system benefits

CONSORTIUM LEAD

SYSTEMIQ

CONSORTIUM PARTNERS

acatech | Audi | BASF We create chemistry | BMW GROUP | Circulor

FIWARE FOUNDATION | Fraunhofer IPK | TWAICE | umicore | VDE RENEWABLES*

*under subcontract

Kick-off event of the Battery Pass consortium in Berlin in April 2022

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The Battery Pass consortium draws upon a network of associated and supporting partners and guidance of its Advisory Council

The Battery Pass partner network

Associated Partners

Global Battery Alliance, GS1 in Europe, Mercedes-Benz, RWE, SAP

Supporting Partners

AIT Austrian Institute of Technology, Alpha Venturi, Battery Associates, Battery Damage Service, batwoman, betteries, CATL, cidetec energy storage, Circular Cars Initiative, Daimler Truck, DENSO Crafting the Core, DEKRA, DIN, DKE, DMT, energy web, Henkel, Honda R&D Europe (Deutschland), INOBAT AUTO, Jungheinrich, LG Energy Solution, LiBCycle, Li-Cycle, LogBATT, LRP Autorecycling, MORROW, NIO, northvolt, PEM Motion, RockTech Lithium, SINE, sonnen, Spherity, Stiftung GRS Batterien, StoreDot, TÜV Verband, Uni Graz – We work for tomorrow, volytica diagnostics, wbcsd, zvei electrifying ideas

Advisory Council

European Battery Alliance EBA250, DIN, Federal Ministry for Economic Affairs and Climate Action, Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, KLiB Kompetenznetzwerk Lithium-Ionen-Batterien, Transport & Environment, VDE, Wuppertal Institut, zvei electrifying ideas

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The Battery Pass consortium supports and collaborates with other major initiatives active in the digital product passport space

CIRPASS Digital Product Passport

- European Commission "Digital-2021-Trust-01-DIGIPASS" winner
- Kicked off in October 2022 lasting 18 months (March 2024)
- Funding volume: EUR 2 mn
- Partners: 31 organisations
- Objective: build a common understanding of a cross-sectoral DPP
- Focus: Batteries, Textiles, Electronics

Global Battery Alliance

- Leading global voluntary passport initiative
- Objective: enabling transparency and accountability for risks and ESG impacts in EV battery value chains by creating a digital twin of the battery and aggregating data in a battery passport
- 3 early-stage proof of concepts were launched at WEF 2023
- Release of first set of ESG metrics (GHG Rulebook, Child Labour and Human Rights Indices) with additional metrics to follow

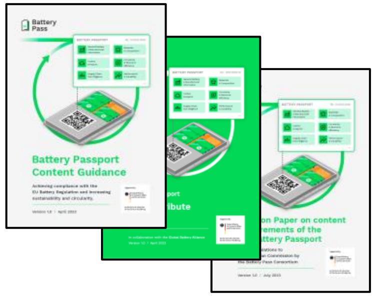
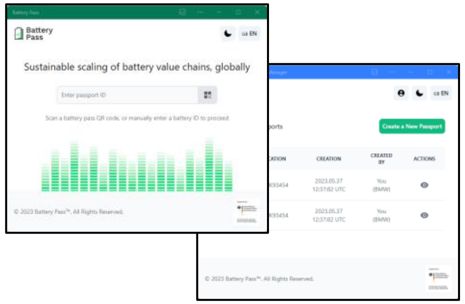
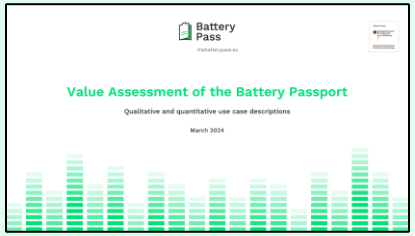
Catena-X Automotive Network

- Developing a comprehensive data ecosystem with standardised global data exchange for data-driven value chain in the automotive industry
- Based on GAIA-X data space technology to support data sovereignty with distributed data management and sophisticated identity and access management
- Focusing on several use cases including decarbonisation and ESG reporting, circularity and battery passport, and others

And many more...

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The scope of our guidance covers content requirements, the standards, architecture, and challenges of the technical passport system, two demonstrator and the value assessment

	Content Guidance	Technical Guidance	Demonstrator	Value Assessment
Objective	Provide comprehensive and timely guidance on the content reporting requirements mandated by the EU battery passport to value chain participants	Provide an overview to economic operators on what the technical battery passport system could look like and which technical standards it should support	Provide a platform which integrates results on battery passport data and system and verifies technological feasibility of the passport	Provide an analytical study to motivate stakeholders along the value chain to use the battery passport proactively and leverage its full potential
Scope	Content Guidance report, data attribute longlist, CO_2 specific documents, EC position paper, outlook on secondary legislation	Technical Standard Stack incl. mapping of existing standards as well as key challenges and recommendations	Software prototype (TRL 5[1]) covering exemplary real-world data as well as physical demonstrator built with LEGO	Exploratory assessment of economic, environmental, and social benefits (1st publication), extended by a net system value assessment (2nd publication)
Publication	 *Originally published in Apr 2023, update in Dec 2023*	 *Published in March 2024*	 *Draft released in March 2024*	 *First of two publications in April 2024*

Focus of this document

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

1. TLR 5: Technology readiness level 5 – technology validated in relevant environment

This document presents the first of two publications from the value assessment and focuses on describing the benefits of individual use cases

Objective

Provide an analytical study to motivate individual stakeholders to use the battery passport proactively and leverage its full potential incl. convincing the European Commission about additional value add potential beyond the current mandatory scope.

Therefore, describe and evaluate potential benefits for businesses, public users and authorities based on qualitative and select quantitative assessments.

Work steps

Exploratory assessment of economic, environmental, and social benefits

- Identification and description of individual use cases
- Qualitative-conceptional evaluation of economic, environmental and social benefits for individual use cases
- Initial quantification of economic, environmental and social benefits for selected use cases

Focus of this document

Exploratory assessment of economic, environmental, and social benefits and net system value

- Qualitative-conceptual evaluation of systemic perspective of a battery passport and its multiple use cases and impacts
- Quantification of aggregated battery passport benefit
- Inclusion of costs, requirements and net-effects of a battery passport in the value assessment

To be released September 2024

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Chapter 3: Methodology

The use case assessment has been a collaborative effort of the consortium and validated by external stakeholders to incorporate the perspective of the battery value chain

Methodological process for the value assessment

Battery Pass consortium partner perspective	**15** Consortium group meetings	• Developed the methodology and use case longlist • Reviewed qualitative and quantitative use case assessments
	6 Sub-working groups	• Developed the qualitative and quantitative use case assessments • Performed additional cross-cutting analyses
External battery industry perspective	**>30** Expert interviews	• Provided expertise on use cases and value chain perspectives • Reviewed qualitative and quantitative assessments and assumptions
	2 Public consultations	• Provided feedback on methodology and use case longlist • Highlighted additional use cases and value add potentials

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The overall assessment includes all battery categories requiring a passport, deep dive focus on EV batteries, and a separate analysis on differences for industrial batteries

Battery categories included in the value assessment

All battery categories requiring a battery passport

- **EV batteries**
- **Industrial batteries with capacity > 2 kWh**
- **LMT**

General use case assessment

- Overall use case description includes all relevant battery categories
- Does not consider the detailed differences of these categories

Deep dive analyses

- Deep dive analysis (qualitative assessment and initial quantification) with more narrow system boundaries due to its complexity
- EVs selected as they represent the largest number of batteries requiring a battery passport

Separate analysis on differences for industrial batteries

- Separate analysis for industrial batteries as they encompass different battery chemistries and system designs
- Differentiates the use case applicability by specific characteristics of industrial batteries

This value assessment did not include a specific analysis for LMT batteries. Such an analysis will be included in the second part of this work package.

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The scope includes mandatory requirements as well as voluntary additions and differentiates between benefits and drawbacks in three impact dimensions

Scope of the value assessment

1 **Requirements** Mandatory + voluntary additions	**Value add from current regulatory scope** as defined by the EU Battery Regulation	+	Additional **value add possibilities** enabled by conditions **beyond regulatory requirements**
2 **Value** Benefits vs. drawbacks	**Benefits** • Enabled by so called "direct" and "potential" use cases along the life cycle • Result in positive impacts for different stakeholders (businesses, private consumer, authorities)	**vs.**	**Drawbacks** • Resulting from challenges stakeholders face when implementing and maintaining the passport requirements • Could reduce the overall benefit

3 **Impact dimensions**

- **Economic** (e.g. cost efficiency)
- **Environmental** (e.g. GHG emissions)
- **Social** (e.g. health and safety)

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

1 While mandatory requirements result from the regulatory text, voluntary aspects are identified by exploring value add potentials beyond the regulatory scope

	Source		Further insights
Mandatory requirements	 REGULATIONS	• Art. 77 and Annex XIII of the EU Battery Regulation as published in the Official Journal of the European Commission • Content Guidance by the Battery Pass consortium	• Most data attributes need to be reported irrespectively of the battery passport, only select ones exclusively for it • Each data attribute is assigned to a list of predefined access groups: – General public – Notified bodies, market surveillance authorities and the Commission – Any natural or legal person with a legitimate interest • Full interoperability with other digital product passports and a high level of security and privacy are to be ensured
Voluntary additions	Battery Pass	• Battery Pass value assessment working group	• Additional voluntary data attributes considered a value add • Upstream traceability through interconnected traceability systems • Integration of passport with other processes and systems • Enablement of systems for data aggregation

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

2 Benefits and drawbacks have been derived and assessed in a three-step approach

Approach

Benefits

1 Identification of "use cases" and allocation on value chain

- "Direct" use cases enabled by access to data attributes in the battery passport as of EU Battery Regulation requirements
- "Potential" use cases enabled by conditions beyond regulatory requirements (e.g. traceability, data aggregation)

2 Qualitative description and assessment of all use cases

- Situation without battery passport and improvement potential through battery passport described
- Economic, environmental and social benefit assessed for three stakeholder groups: businesses, private consumers and authorities

3 Deep dive analysis of selected use cases incl. quantification

- Selection based on (1) value add potential, (2) quantifiability, (3) value chain coverage, (4) use case type (direct vs potential)
- Quantification of one indicator per impact dimension: (1) economic: revenue or cost, (2) environmental: GHG emissions, and (3) cross-cutting: secondary material availability/primary materials avoided

Focus of the assessment

Challenges and drawbacks

1 Identification of challenges for stakeholders

- Technical and battery passport system challenges
- Capability and resource challenges

2 Evaluation of significance (industry focus)

- Based on "role" of organisation (e.g. data provider, data receiver) for technical and battery passport system challenges
- Based on size and capabilities (e.g. SME or MNC)[1] of organisation for capability and resource challenges

3 Assessment of possible negative impacts

- Resulting from unmitigated challenges stakeholders are facing
- Categorised by economic, environmental and social impact dimensions

Only initial qualitative indication

1. SME: Small and medium-sized enterprise; MNC: Multi-national corporation

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

3 In general, the impact assessment covers an economic, environmental and social dimension as well as a cross-cutting one for the quantification

BENEFITS – NOT EXHAUSTIVE AND EXEMPLARY

[ ] Used for quantification of selected deep dive use cases[1]

Economic

- Gross domestic product increase
- Revenue increase [dashed box]
- Cost decrease [dashed box]
- Immaterial value creation

Environmental

- GHG emissions decrease [dashed box]
- Water pollution decrease
- Biodiversity preservation
- Natural resource conservation

Social

- Upheld human rights standards
- Creation of local jobs
- Improved governance structures
- Health and safety increase

Cross-cutting

- Secondary materials available / primary material avoided [dashed box]
- Reduced waste

1. Please refer to the quantitative assessment of the selected use cases for a detailed methodology on the respective quantification

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

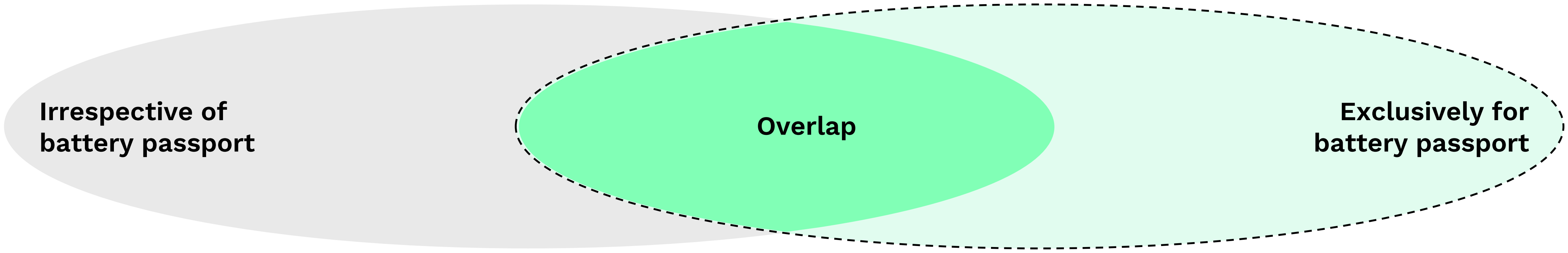
Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
- Analysis on differences for industrial batteries

The battery passport provides added value to general requirements from the Battery Regulation by collecting data in a digital format and making it accessible

Battery Regulation reporting requirements

Scope where battery passport provides added value to Battery Regulation reporting requirements[1]



Battery passport benefits (data and systems)

- Information **collected** in a harmonised manner[2]
- Information **made accessible** to different stakeholders
- Information **digitised and converted into an interoperable format**

1. See Annex (slide 131) for the list of exact data attributes per category and refer to the Battery Pass Content Guidance (Battery Pass consortium (2023a)) for detailed reporting requirements
2. Benefits apply only to exclusive battery passport requirements; in overlap section information already needs to be collected in a harmonised manner for requirements irrespective of the battery passport

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Benefits resulting from using the battery passport are enabled by so called "use cases"

Key terms used in the "benefits" chapter

Use cases	… **describe processes which could be improved by using the passport** and are **identified to understand which** economic, environmental and social **benefits could arise** from the battery passport
Direct use cases	…are **enabled by access to mandatory data attributes as of EU Battery Regulation requirements**
Potential use cases	…are enabled by **conditions beyond regulatory requirements** (e.g. traceability, data aggregation, process integration)
User	…describes the **individual or organisation accessing information via the battery passport** (process improvements could also lead to benefits for stakeholders beyond the core user)

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

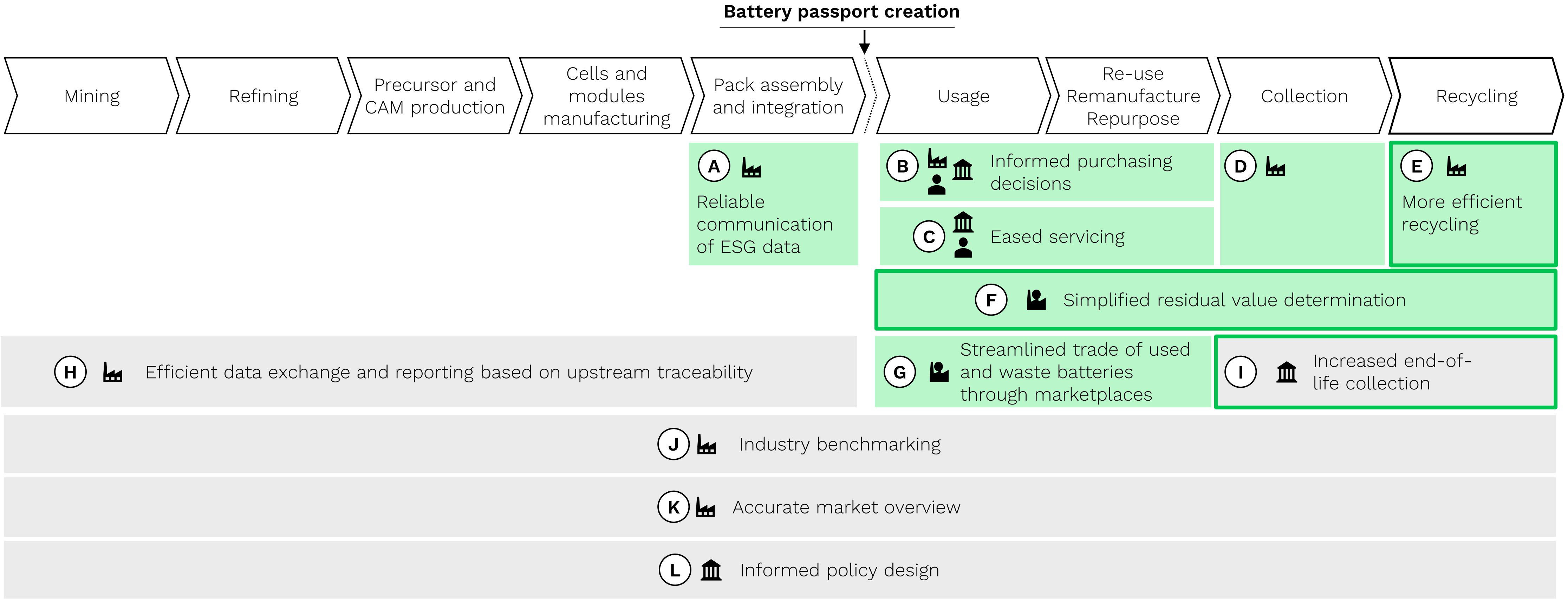
Overall, 12 use cases of the battery passport were identified along the value chain

Battery passport user: Business Authority Private consumer

Direct use case

Potential use case

Selected for qualitative deep dive and initial quantification



Note: Use cases are allocated along the value chain step(s) in which the battery passport is used

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Brief qualitative-conceptional use case description (1/3)

Battery passport user: Business, Authority, Private consumer **Benefit:** Economic, Environmental, Social **Level of benefit:** No, Low, Middle, High

Use case	Short description	Type	User	Benefit: Economic	Benefit: Environmental	Benefit: Social	Links
A	**Reliable communication of ESG data** Companies selling batteries with outstanding ESG performance (e.g. due diligence report, carbon footprint) could leverage the battery passport for product differentiation.	Direct	Business	Middle	Low	Low	*One Pager*
B	**Informed purchasing decisions** Access to reliable and comparable information about the battery (e.g. carbon footprint and durability) facilitates well-informed purchasing decisions.	Direct	Business, Authority, Private consumer	Middle	Middle	Low	*One Pager*
C	**Eased servicing** Information on the design and characteristics of the battery (e.g. dismantling information, spare part supplier) facilitate servicing activities, especially for independent workshops.	Direct	Business, Private consumer	Middle	Middle	Low	*One Pager*
D	**Precise risk assessment for transport of used batteries** Information about the history of the battery (e.g. accidents, number of deep discharge events) supports the correct categorisation and thereby minimises the risk of using insufficient transport precautions.	Direct	Business	Middle	Low	Low	*One Pager*

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Brief qualitative-conceptional use case description (2/3)

Battery passport user: Business | Authority | Private consumer **Benefit:** Economic | Environmental | Social **Level of benefit:** No | Low | Middle | High

Use case	Short description	Type	User	Benefit: Economic	Benefit: Environmental	Benefit: Social	Links
E	**More efficient recycling processes** Availability of data on battery composition and dismantling enables more efficient recycling processes by e.g. reducing sampling efforts and optimising the dismantling process.	Direct	Business	High	Low	Middle	*One Pager* *Deep Dive*
F	**Simplified residual value determination** Performance and durability data (e.g. remaining capacity, internal resistance) enable downstream businesses and private users to better assess the residual value of the battery to decide between recycling or second life and its specific second-life application.	Direct	Business, Private consumer	High	Middle	No	*One Pager* *Deep Dive*
G	**Streamlined trade of used and waste batteries through marketplaces** Marketplaces could optimise the matching of supply and demand by utilising comparable information from battery passports, connecting buyers with suitable batteries and reducing transaction costs.	Direct	Business, Private consumer	Middle	Low	No	*One Pager*
H	**Efficient data exchange and reporting based on upstream traceability** Indirectly enabled by the battery passport requirements, upstream traceability systems could enable the exchange of company-specific data in supply chains, providing a tool for efficient and dynamic data reporting with increased credibility and reliability.	Potential	Business	Middle	Low	Low	*One Pager*

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Brief qualitative-conceptional use case description (3/3)

Battery passport user: Business, Authority, Private consumer **Benefit:** Economic, Environmental, Social **Level of benefit:** No, Low, Middle, High

Use case	Short description	Type	User	Benefit: Economic	Benefit: Environmental	Benefit: Social	Links
I	**Increased end-of-life collection** Additional downstream information could support authorities in preventing “battery leakage” (illegal exports and treatment) by leveraging the passport for export control and market surveillance.	Potential	Business	High	High	Middle	*One Pager* *Deep Dive*
J	**Industry benchmarking** Data aggregated from battery passports could be used for own benchmarking purposes (e.g. of performance and sustainability indicators) or to guide consumer and investor decisions.	Potential	Business	High	Middle	Low	*One Pager*
K	**Accurate market overview** Information aggregated from batteries on the market, including status and expected lifetime, could market studies and projections, aiding business planning activities along the value chain.	Potential	Business	Middle	Low	No	*One Pager*
L	**Informed policy design** More accurate data on the battery stock in the different life cycle stages (e.g. material volumes) aggregated from different battery passports could provide information for fact-based policy design.	Potential	Authority	Middle	High	Low	*One Pager*

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Different use cases are interdependent, influencing one another through amplifying or delaying effects

A: Reliable communication of ESG data

B: Informed purchasing decisions

C: Eased servicing

D: Precise risk assessment for transport of used batteries

E: More efficient recycling

F: Simplified residual value determination

G: Streamlined trade of used and waste batteries through marketplaces

H: Efficient data exchange and reporting based on upstream traceability

I: Increased end-of-life collection

J: Industry benchmarking

K: Accurate market overview

L: Informed policy design

2 →

1 ↓

	A	B	C	D	E	F	G	H	I	J	K	L
A		+								+		+
B												
C												
D		+	+		+	+	+		+			
E	+											
F		+			-		+					
G					-							
H	+	+										
I					+							
J	+	+									+	+
K												+
L												

"+" use case 1 amplifies use case 2

"-" use case 1 delays use case 2

Examples

- Use case A amplifies use case B: Due to companies leveraging the battery passport to reliably communicate the ESG performance of a product, customers are empowered to make more informed purchasing decisions.
- Use Case F delays use case E: Due to the dynamic data on the battery passport, the residual value determination gets simpler, i.e., fewer tests are required to evaluate whether a battery is suitable for a second-life. Consequently, more batteries will be re-used, remanufactured or repurposed, therefore the recycling of these batteries is delayed.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

All use cases are further described using the following overview structure

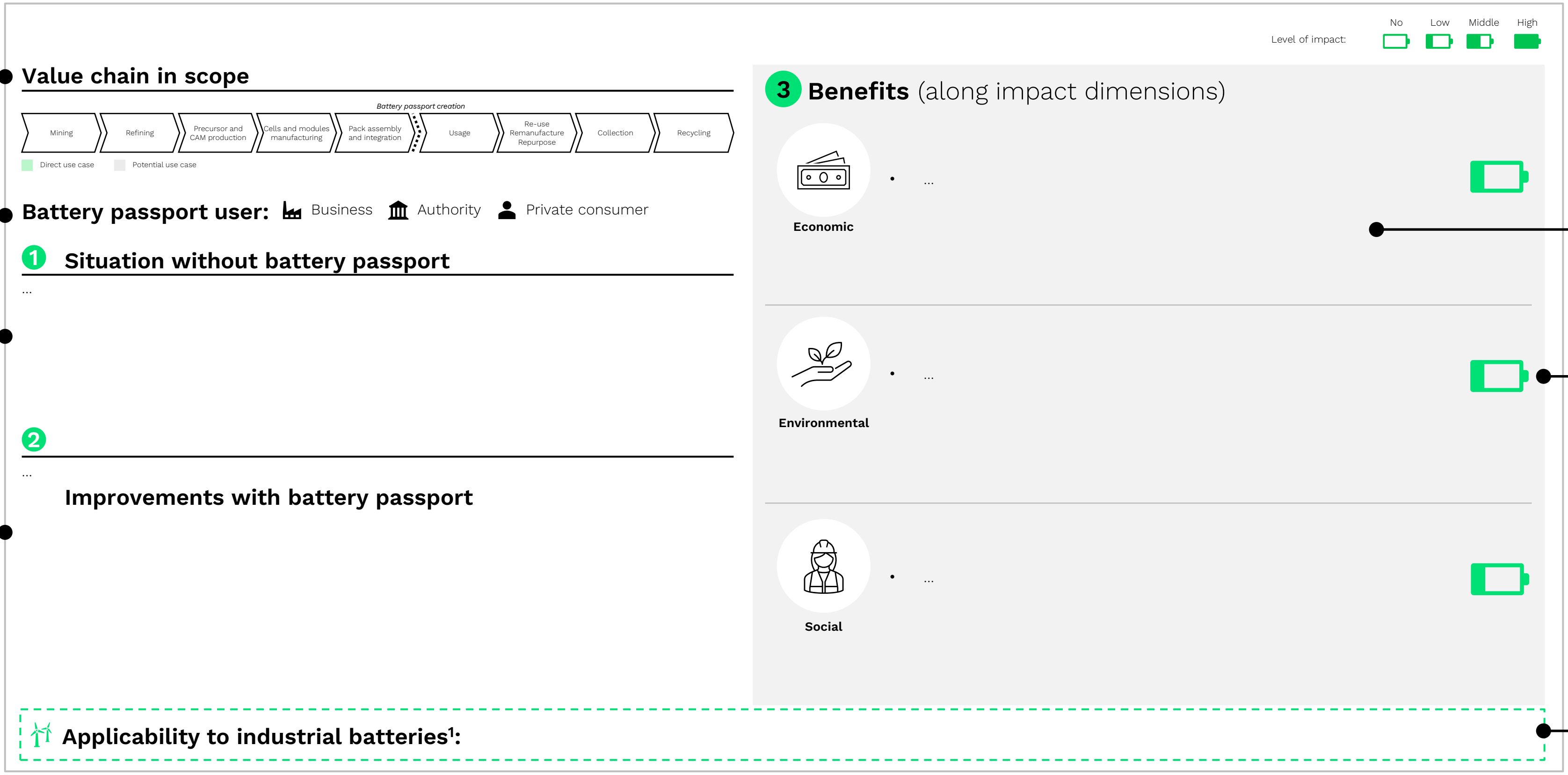
Core elements of use case "one pagers"

Applicability of use case by value chain steps and indication of use case type

User group accessing battery passport information

Current process incl. existing information gaps

Process improvements enabled by information available from battery passport



Description of benefit by impact dimensions

Assessment of level of impact

Indication on applicability of use case to industrial batteries

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

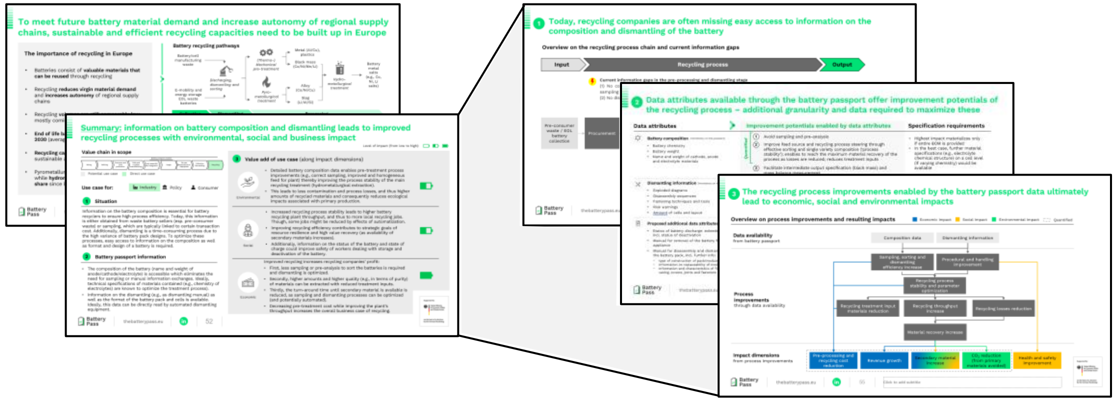
Selected use cases are chosen for a deep dive including further qualitative details as well as an initial quantification of the impact

Selected deep dive use cases

- (E) More efficient recycling (direct use case – see slides 57 - 68)
- (F) Simplified residual value determination (direct use case – see slides 69 - 79)
- (I) Increased end-of-life collection (potential use case – see slides 90 - 100)

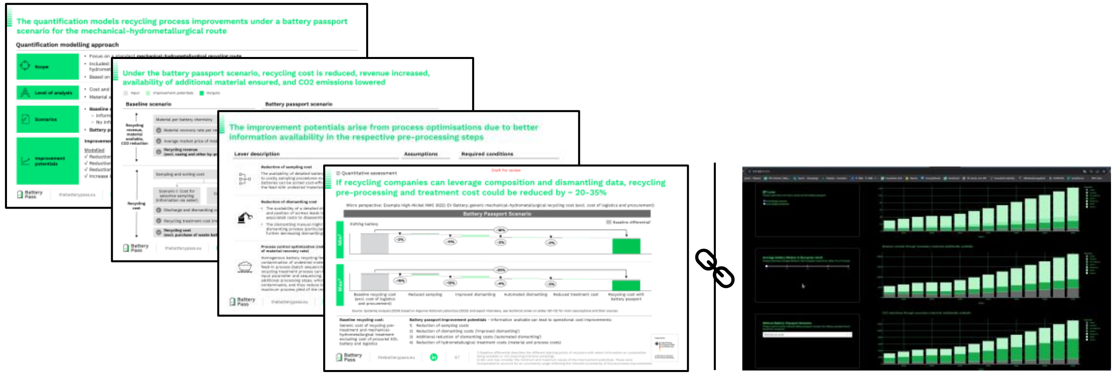
Qualitative assessment

- Introduction to market need and problem statement
- Deep dive into the three categories of the "one pager" summary
  1. Situation without the battery passport
  2. Improvements with the battery passport
  3. Benefits (along impact dimensions)



Quantitative assessment

- Description of quantification modelling approach
- Overview on analytical quantification steps
- Details on levers, assumptions and required conditions
- Calculation results
- Interactive visualisation



Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
  - Use case descriptions
  - Deep dives
- Potential use cases
- Analysis on differences for industrial batteries

Direct use cases result from mandatory data attributes required by the EU Battery Regulation in combination with the respective access rights

Mandatory data attributes and their respective access rights enable seven direct use cases:

Mandatory data attributes[1]	+	Access rights[2]	=	A	B	C	D	E	F	G
General information		Public or persons with a legitimate interest					X			X
Labels and certifications		Public or notified bodies, market surveillance authorities and the Commission			X					X
Carbon footprint		Public		X	X					
Supply chain due diligence		Public		X	X					X
Materials and composition		Public or persons with a legitimate interest and the Commission			X		X	X	X	X
Circularity and resource efficiency		Public or persons with a legitimate interest and the Commission		X	X	X		X		
Performance and durability		Public or persons with a legitimate interest and the Commission			X	X	X		X	X

Direct use cases

- (A) Reliable communication of ESG data
- (B) Informed purchasing decisions
- (C) Eased servicing
- (D) Precise risk assessment for transport of used batteries
- (E) More efficient recycling processes
- (F) Simplified residual value determination
- (G) Streamlined trade of used and waste batteries through marketplaces

1. Only overarching data categories listed
2. Can vary between different data attributes in one category

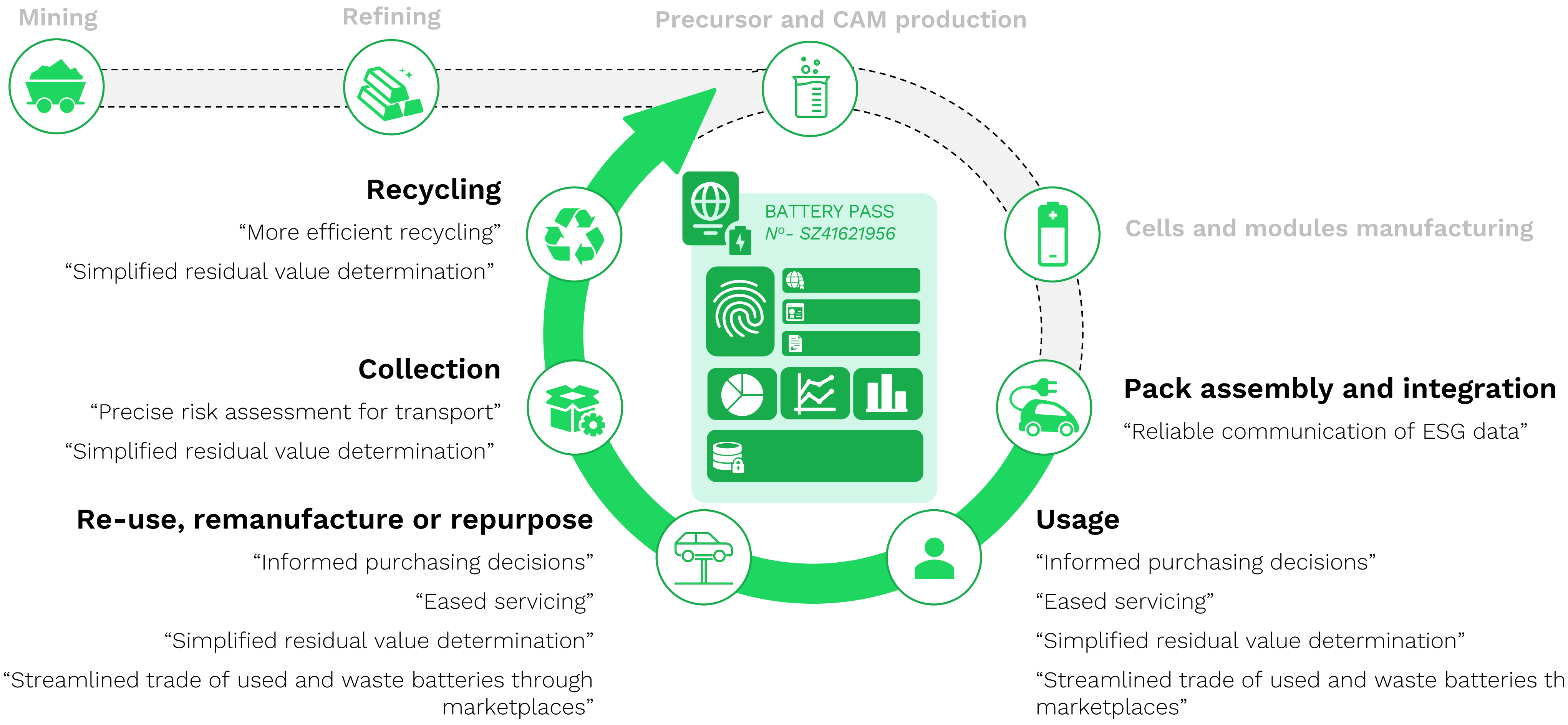
Please refer to the Battery Passport Content Guidance (Battery Pass consortium (2023a)) for more information on the data attributes

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Direct use cases of the battery passport mainly unlock value along the downstream value chain

EXEMPLARY

Value of the passport:
- Potential additional value beyond regulatory compliance pending conditions beyond regulatory requirements (see "potential" use cases)
- Direct value add along several dimensions (environmental, social and economic)



Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
  - Use case descriptions
  - Deep dives
- Potential use cases
- Analysis on differences for industrial batteries

A Reliable communication of ESG data: Companies selling batteries with outstanding ESG performance could leverage the battery passport for product differentiation

Level of impact: No | Low | Middle | High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case | Potential use case | Not applicable

Battery passport user: Business | Authority | Private consumer

1 Situation without battery passport

In light of new regulations and increasing sustainability requirements of customers, responsible economic operators (and suppliers to a certain extent) need to communicate various ESG data to ensure compliance and differentiate themselves from competitors. Today, this is often not done in a comparable and credible manner.

2 Improvements with battery passport

The battery passport is expected to increase customer awareness of product ESG performance. Companies selling batteries could leverage the passport for a reliable communication as it provides direct access to the following upstream information that needs to be calculated, verified and reported in the context of the EU Battery Regulation:

- Carbon footprint (carbon footprint as declared and performance class)
- Supply chain due diligence (information indicated in the due diligence report)
- Circularity and resource efficiency (recycled content)

Further ESG information based on harmonised methodologies and verified under different regimes (e.g. human rights and child labour indices by the GBA) could be added on a voluntary basis.

3 Benefits (along impact dimensions)

Economic

- Economic operators excelling on ESG performance of their products could attract eco-conscious consumers as well as green public procurement, secure sustainable investment, and enhance brand reputation thereby driving revenue and long-term economic success

Environmental

- Carbon footprint and recycled content information are made transparent for consumers. This incentivises economic operators to improve their environmental impact to outperform competitors

Social

- Consumer access to the due diligence report could encourage economic operators to proactively mitigate social risks in their supply chains (e.g. human rights violations)

Applicability to industrial batteries[1]: Equally applicable for all industrial batteries

1. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

B Informed purchasing decisions: Access to reliable and comparable information about the battery facilitates well-informed purchasing decisions

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case | Potential use case | Not applicable

Battery passport user: Business | Authority | Private consumer

1 Situation without battery passport

Technical performance and sustainability crucially determine the decision to buy a battery. In a continuously growing market, public and private purchasers require trusted, transparent, and comparable information about a battery to make an informed decision, which today is not easily available in a harmonised manner. This holds true both for a new and used battery.

2 Improvements with battery passport

The following information on a battery's technical performance and sustainability is designated for public access and could empower end-consumers to make informed purchasing decisions:

- Labels and certifications (symbols and labels, declaration of conformity)
- Carbon footprint (carbon footprint as declared and performance class)
- Supply chain due diligence (information indicated in the due diligence report)
- Materials and composition (battery chemistry)
- Circularity and resource efficiency (recycled content, information on separate collection etc.)
- Performance and durability (rated capacity, expected lifetime etc.)

3 Benefits (along impact dimensions)

Economic

- Access to labels and certifications as well as performance and durability information, such as rated capacity and expected lifetime, empowers buyers to make economically sound decisions considering the resale value when buying a first life battery and negotiating the purchase price for second-life batteries
- Information on the battery chemistry enables educated buyers to select the most suitable chemistry based on their specific needs, optimising its usage and extending the battery's longevity, ultimately translating into financial savings and value

Environmental

- Private and corporate end-consumers, as well as purchase departments of public institutions that leverage the data for green public procurement policies, could reduce the impact on the environment by deciding in favour of more sustainable batteries and putting pressure on manufacturers to improve on e.g. GHG emissions

Social

- Information on supply chain due diligence enables consumers to decide in favour of batteries meeting certain social sustainability standards along the battery supply chain, thereby putting pressure on manufacturers to improve [1]

Applicability to industrial batteries[2]: Equally applicable for industrial batteries with BMS | Less applicable for industrial batteries without BMS

1. The battery passport connects to a Due Diligence report outlining social risks and mitigation measures by the economic operator. In contrast to the environmental indicators, this information is not easy to evaluate or compare, diminishing the effectiveness of this benefit
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

C Eased servicing: Information on the design and characteristics of the battery could facilitate servicing activities, especially for independent repair workshops

Level of impact: No, Low, Middle, High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | **Usage** | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case · Potential use case · Not applicable

Battery passport user: Business (applicable) · Authority · Private consumer (applicable)

1 Situation without battery passport

Limited access to technical information and a lack of standardisation make professional servicing of batteries difficult, especially for independent repair workshops[1]. This results in a limited range of service options and thus restricts consumer choice of repair shops.

2 Improvements with battery passport

The following passport information about the battery's state and handling instructions could ease the servicing, especially for independent workshops:

- Circularity and resource efficiency (manuals for removal as well as disassembly and dismantling, contact details for spare parts, safety measures and instructions)
- Performance and durability (state of charge, current internal resistance, number of deep discharge events, accidents, etc.)

As a prerequisite, service providers are to be designated as "interested persons" to gain access to the respective passport information.

3 Benefits (along impact dimensions)

Economic (impact: Middle)

- Leveraging the available data enables workshop technicians to streamline the diagnosis of battery issues and repair procedures, thereby saving valuable time and effort
- Performance and durability information could be used to provide handling advice to users aiming for increased battery lifetime, which results in a reduced cost of ownership

Environmental (impact: Middle)

- Eased servicing could extend the lifetime of batteries and therefore lowers GHG emissions since fewer batteries and materials are required
- Repair enabled by available data could minimise spare part usage thereby conserving resources

Social (impact: Low)

- Decentralised access to passport data could foster localised repair shops thereby creating local employment opportunities

Applicability to industrial batteries[2]: – Less applicable for all industrial batteries

1. Independent repair workshops refer to competent and certified workshops that are operating independently of the original manufacturers or brands
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

D Precise risk assessment for transport of used batteries: Information about the history of the battery minimises the risk of insufficient transport precautions

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining → Refining → Precursor and CAM production → Cells and modules manufacturing → Pack assembly and integration → Usage → Re-use Remanufacture Repurpose → **Collection** → Recycling

Direct use case / Potential use case / Not applicable

Battery passport user: **Business** | Authority | Private consumer

1 Situation without battery passport

Transporting used batteries involves the risk of dangerous reactions in the case of defects. Compliance with international regulations for transporting hazardous goods, requires battery categorisation. Currently, this categorisation relies heavily on optical evaluation, which is insufficient for accurately assessing battery risks.
Furthermore, the Battery Regulation differentiates between "waste batteries" and "used batteries." Shipping used batteries requires testing the State of Health and evaluating hazardous substances (Article 72 and Annex XIV). On the other hand, shipping waste batteries involves obtaining permits, which is a time-consuming process.

2 Improvements with battery passport

- Battery passport information on performance and durability (e.g. state of charge, current internal resistance, time spent in extreme temperatures, number of deep discharge events, accidents, etc.) could support the correct categorisation and thereby minimise the risk of insufficient transport precautions
- Furthermore, the following passport information could support the distinction between “waste” and “used” batteries[1]
  - General battery and manufacturer information (battery identification)
  - Battery materials and composition (hazardous substances)
  - Performance and durability (capacity fade)

3 Benefits (along impact dimensions)

A correct categorisation and corresponding precautions (a) as well as a clearer distinction between “waste” and “used” batteries (b) could enable businesses collecting batteries to:

Economic (impact: Middle)
- Enhance transport safety and reduce the financial risk for battery shippers (a)
- Avoid time-consuming waste transportation permits, leading to a reduction of battery storage costs (b)

Environmental (impact: Low)
- Reduce incidents thereby limiting environmental pollution (a)

Social (impact: Low)
- Reduce accidents thereby limiting threats to health and safety of transportation personnel (a)

Applicability to industrial batteries[2]: ✓ Equally applicable for industrial batteries with BMS | – Less applicable for industrial batteries without BMS | X Not applicable for industrial batteries with external storage

1. It still needs to be assessed whether the information available via the battery passport is sufficient to comply with the testing requirements of Article 72 and Annex XIV
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

E More efficient recycling: Availability of data on battery composition and dismantling could increase process efficiency by e.g. reducing sampling efforts

Level of impact: No, Low, Middle, High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case | Potential use case | Not applicable

Battery passport user: Business | Authority | Private consumer

1 Situation without battery passport

Information on the battery composition is essential for battery recyclers to ensure high process efficiency. Today, this information is either obtained from waste battery sellers (esp. pre-consumer waste) or sampling, which are typically linked to certain transaction costs. Additionally, dismantling is a time-consuming process due to the high variance of battery pack designs. To optimise these processes, easy access to information on the composition as well as format and design of a battery is required.

2 Improvements with battery passport

- The composition of the battery (name and weight of anode/cathode/electrolyte) is accessible via the battery passport, which could eliminate the need for sampling or manual information exchanges – ideally, technical specifications of materials contained (e.g. chemistry of electrolytes) are known to optimise the treatment process[1]
- Furthermore, information on the dismantling (e.g. as dismantling manual) as well as the format of the battery pack and cells is available – ideally, this data could be directly read by automated dismantling equipment
- The availability of battery passport information on performance and durability (e.g., state of charge, time spent in extreme temperatures, number of deep discharge events, accidents etc.) could enable an optimal battery deactivation
- As a prerequisite, authorised recycling companies are to be designated as "interested persons" to gain access to the respective passport information

3 Benefits (along impact dimensions)

Economic (Level of impact: High)

Information availability via the battery passport could decrease the costs of the recycling process:

- Less sampling or pre-analysis to sort the batteries is required and discharge and dismantling could be optimised
- More materials could be recovered with reduced treatment inputs (reduction of process losses due to lower contamination)
- Faster turnaround times for secondary materials, as sampling and dismantling processes could be optimised (and potentially automated)
- Decreasing pre-treatment cost while improving the plant's throughput could increase the overall business case of recycling

Environmental (Level of impact: Low)

- Detailed battery composition data could enable pre-treatment process improvements (e.g. correct sampling, improved and homogeneous feed for plant) that increase the process stability of the main recycling treatment (hydrometallurgical extraction), resulting in less contamination and process losses and thus higher quantities of recycled materials and consequently reducing the environmental impact associated with primary production

Social (Level of impact: Middle)

- Information on performance and durability (e.g. status of the battery and state of charge) could improve safety of workers dealing with storage and deactivation of the battery
- Increased recycling process stability through information availability could lead to higher battery recycling plant throughput, and thus to more local recycling jobs - though some jobs might be reduced by effects of automation
- Improving recycling efficiency through available information could contribute to strategic goals of resource resilience and high value recovery

Applicability to industrial batteries[2]: ✓ Equally applicable for industrial batteries with Li-Ion and emerging chemistries | – Less applicable for industrial batteries except Li-Ion and emerging chemistries

1. It still needs to be assessed whether the information available via the battery passport is sufficient to comply with the testing requirements of Article 72 and Annex XIV
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

F Simplified residual value determination: Performance and durability data could support in assessing the residual monetary value as well as remaining useful life

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case | Potential use case | Not applicable

Battery passport user: Business | Authority | Private consumer

1 Situation without battery passport

The residual value (monetary as well as remaining useful life) is a crucial indicator to manage used batteries, i.e. assess their resale value and decide between recycling or second-life applications. Today, it is challenging for independent second-life operators[1] or end-consumers to accurately assess the residual value of batteries due to a lack of standard procedures on measuring the battery's state of health and reporting on its historic usage. Therefore, time-consuming as well as costly tests are required.

2 Improvements with battery passport

The following battery passport information on battery characteristics and historic usage of the battery simplify the residual value determination by reducing the effort for initial technical tests[3], which could also increase the number of batteries going into a second life:

- Battery materials and composition (battery chemistry)
- Performance and durability (capacity fade, State of certified energy (SOCE), current internal resistance, accidents etc.)

As a prerequisite, second-life operators and end-consumers are to be designated as "interested persons" to gain access to the respective passport information.

3 Benefits (along impact dimensions)

Economic (impact: High)

- Easy access to information on the first life of the battery reduces the need for costly tests to estimate the residual value of a battery[3]
- Reliable and comparable performance data facilitates a transparent resale value determination which could lead to increased revenue of the battery seller or lower cost of the buyer

Environmental (impact: Middle)

- An improved allocation between recycling and second-life could increase the quantity of batteries being re-used, remanufactured or repurposed, thereby reducing the need for primary raw material extraction and lowering GHG emissions associated with battery production

Social (impact: No)

- N/A

Applicability to industrial batteries[2]: – Less applicable for all industrial batteries

1. Independent second-life operators refer to businesses that specialise in repurposing or reusing batteries that are operating independently of the original manufacturers or brands
2. For more information, please refer to subchapter on slides 110-119
3. This refers to technical tests needed to determine the resale value or whether a battery is suitable for a second-life application; advanced and costly tests are still required to certify a battery for second-life usage (e.g. the current industry standard UL-1974)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

G Streamlined trade of used and waste batteries through marketplaces: Reliable and comparable data from passports could be used to connect buyers with batteries

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | **Usage** | **Re-use Remanufacture Repurpose** | Collection | **Recycling**

Direct use case / Potential use case / Not applicable

Battery passport user: **Business** | Authority | **Private consumer**

1 Situation without battery passport

Today, most used and waste batteries are traded via direct contractual arrangements. This includes high transaction costs as information exchange between a large network of decentralised collectors and sellers needs to be organised. Some marketplaces already exist, but unreliable and incomparable information make it challenging to establish a trustworthy foundation for purchase decisions. Consequently, additional tests are often required further escalating procurement costs.

2 Improvements with battery passport

- Access to battery passport information via marketplaces could increase the availability, reliability and comparability of decision-relevant information and thus connect buyers with the most suitable batteries for the desired application. Relevant information from different battery passports are e.g.:
  - General information (manufacturing information, battery weight)
  - Labels and certifications (symbols and labels, declaration of conformity)
  - Materials and composition (battery chemistry)
  - Performance and durability data, e.g.: remaining capacity or energy, expected lifetime, age distribution, negative events
- Additional voluntary data like physical damage data could enable a more effective end-of-life allocation process
- As a prerequisite, operators submitting used batteries to marketplace are to be designated as “interested persons” to gain access to the dynamic passport data

3 Benefits (along impact dimensions)

A marketplace integrates battery passports and its information and thus could:

Economic (impact: Middle)

- Significantly reduce transaction costs through more reliable and comparable information available for both buyers and sellers of used and waste batteries, fostering cost savings, e.g. by avoiding or reducing technical tests
- Provide easy access for buyers to large quantities of used and waste batteries to enable resource strategies (e.g. for second-life applications, securing feedstock for recycling)

Environmental (impact: Low)

- Foster a more effective allocation of used and waste batteries as information on usage and performance enable the allocation to remanufacturing, repurposing or recycling, thereby extending the lifetime, e.g. in second-life applications to reduce resource needs, where used batteries were previously recycled

Social (impact: No)

- N/A

Applicability to industrial batteries[1]: Equally applicable for all industrial batteries

1. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
  - Use case descriptions
  - Deep dive: (E) More efficient recycling processes
- Potential use cases
- Analysis on differences for industrial batteries

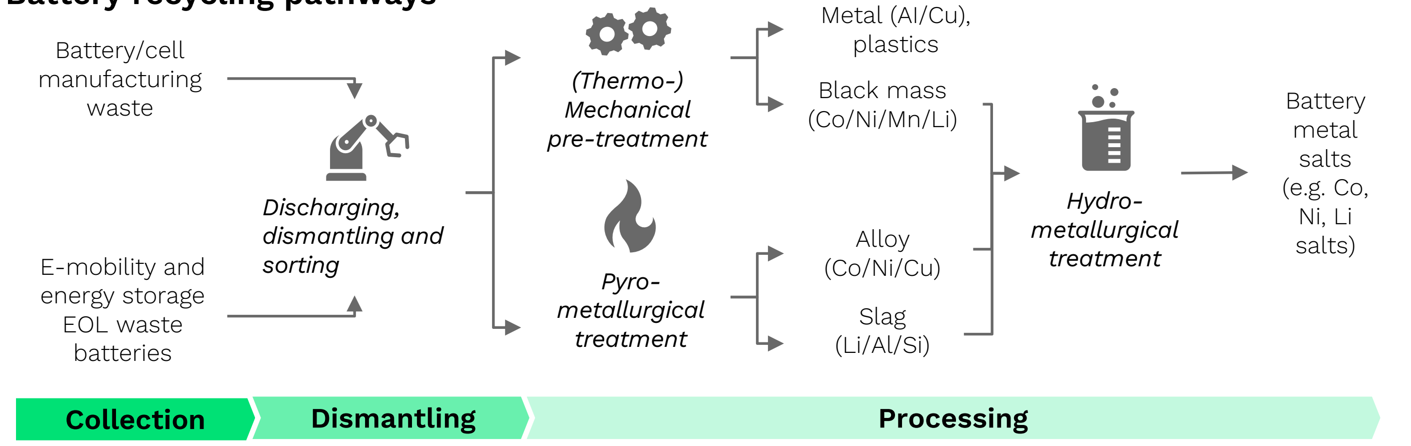
1) Qualitative assessment

To meet future battery material demand and increase autonomy of regional supply chains, sustainable and efficient recycling capacities need to be built in Europe

The importance of recycling in Europe

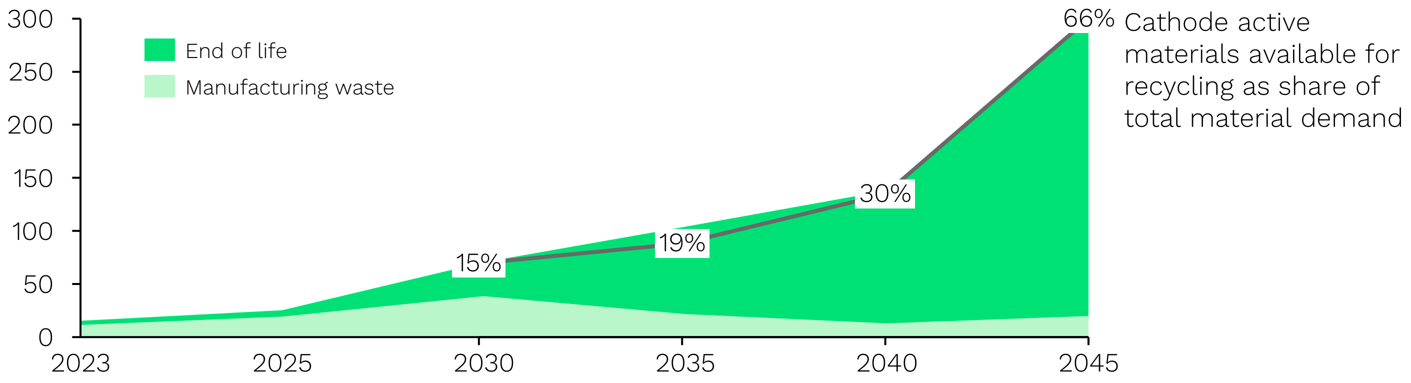
- Batteries consist of **valuable materials that could be re-used** through recycling to **reduce primary material demand** and **increase autonomy** of regional supply chains
- Pyrometallurgical recycling has dominated in the past, while **hydrometallurgical takes over market share** since leading to higher material recovery rates
- In Europe, plants **totalling over 300 kt recycling capacity** (all battery materials)[1] have already been announced – until 2030, **capacities of up to ~900 kt** are expected
- Current recycling **volumes are still low,** mostly coming from manufacturing waste
- **End-of-life battery volumes will rise and surpass manufacturing waste from 2030 onwards** (average battery life 10-14 years)

Battery recycling pathways



EU battery cathode active materials[2] available for recycling and share of demand

Kilotons p.a.



1. Note that these figures include the total weight of battery materials incl. housing, from Fraunhofer ISI (2023)
2. Cathode active materials = cobalt, nickel, manganese, lithium

Sources: Battery Pass consortium (2023b); Battery Pass Use Case Models

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

1) Qualitative assessment

1 Today, recycling companies often lack easy access to information on the composition and for dismantling of the battery

Overview on the recycling process chain and current information gaps

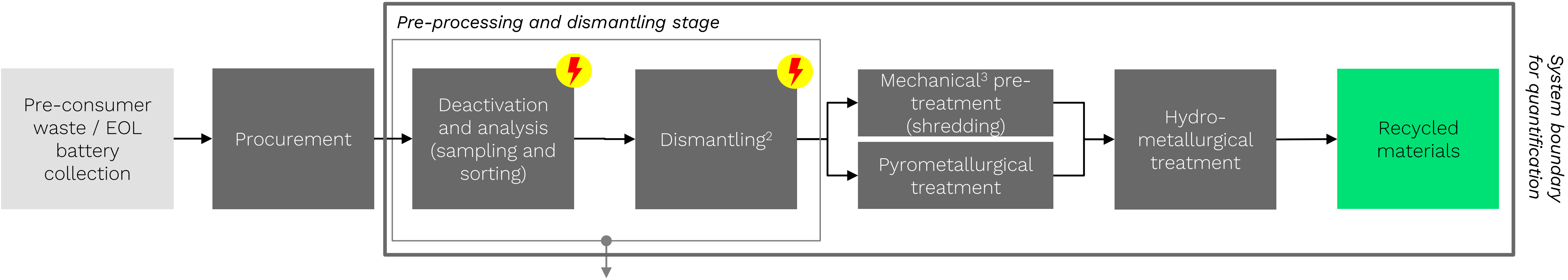
Input | **Recycling process** | **Output**

Current information gaps in the pre-processing and dismantling stage

(a) Lack of battery health status or diagnostic information prevents optimal discharging process

(b) Lack of composition data (or only selectively via seller[1]) leads to transaction cost in the sampling and sorting stage

(b) Lack of dismantling information leads to time-consuming and labour-intensive dismantling process



Access to battery passport data attributes closes current information gaps by avoiding e.g. pre-analysis and sampling and thereby leads to an improved subsequent recycling processes

1. Mostly relevant for pre-consumer waste batteries / off-spec cells and batteries
2. As some battery recyclers shred entire battery packs, the dismantling information gap only exists where battery packs and modules are dismantled.
3. Might include pyrolysis to remove organic compounds (thermal pre-treatment)

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

1) Qualitative assessment

2 Battery passport data offers the potential to improve the recycling process – additional granularity and data is required to maximise these

Data attributes		Improvement potentials enabled by data attributes	Specification requirements
Battery composition *(mandatory on the passport)* • Battery chemistry • Battery weight • Name, weight and detailed composition of cathode, anode and electrolyte materials[1] • Composition of other battery components (e.g. power electronics)[1]	*Quantified* (1–2)	(1) Avoid sampling and pre-analysis (2) Improve feed source and recycling process steering through effective sorting and single variety composition ("process stability"); enables to reach the maximum material recovery of the process as losses are reduced; reduces treatment inputs (3) Facilitate intermediate output specification (black mass) and mass-balance measurement	• Highest impact materialises if entire bill of materials is provided • In the best case, further material specifications (e.g. electrolyte chemical structure) on a cell level (if varying chemistry) would be available, but confidentiality concerns remain due to lack of standardisation[1]
Dismantling information *(mandatory on the passport)* • Exploded diagrams • Disassembly sequences • Fastening techniques and tools • Risk warnings • Number of cells and layout	*Quantified* (4–5)	(4) Optimise battery dismantling process (process efficiency) (5) Automate battery dismantling process through machine-readable format	• Information should be provided in a standardised structure and in machine-readable format (e.g. translating diagrams into text) • Automated dismantling equipment to be set-up
Proposed additional data attributes • Information from previous handling operations – Battery diagnostics – Risk assessment report (if standardised) – status of battery discharge (extended state of charge incl. status of deactivation) • Manual for removal of the battery from the appliance • Manual for disassembly and dismantling of the battery pack, incl. further information: – Type of construction of pack/modules/cells – Information on replaceability of modules/cells – Information and characteristics of fillings, casing, screws, joints and fasteners • Status change attribute "recycled"		(6) Increase operational safety in storage and pre-processing (7) Improve efficiency in process handling if information from previous handling operations can be integrated into recycling pre-treatment (e.g. deactivation) (8) Optimise removal of battery from appliance (safety and procedure) Maximise dismantling optimisation potential, see levers 4 and 5 above (9) Enable recycled material certificate tracing and reporting of recycled content	• Battery passport information need to be integrated into existing safe working procedures (SWPs) and workflows requiring training and other process adoption efforts • Accuracy and reliability of additional attributes must be guaranteed

1. The granularity for providing the detailed composition data and the specification of battery components for which the general composition data will be applicable is not specified in the EU battery regulation with further standardisation required. For further information on the battery passport data attributes, please refer to the Battery Passport Content Guidance (Battery Pass consortium (2023a))

Supported by: Federal Ministry for Economic Affairs and Climate Action, on the basis of a decision by the German Bundestag

1) Qualitative assessment

The battery passport could enable value creation along the battery recycling pre-processing chain if it is integrated in current workflows and procedures

PROCESS VIEW

				Battery passport information	Value creation
EOL EVs, EOL LMT, EOL industrial applications	**Electric vehicle (EV) battery**	**Light means of transport (LMT) battery**	**Industrial battery >2 kWh**		
Removed EOL batteries, production scrap				• Battery composition • Dynamic performance data	• Attributing commercial value to used battery • Managing complexity
	Second-life testing and potential life extension			• General battery information • Dynamic performance data	• Useful life extension
Sorting and sampling at recycler	e.g. NMC	e.g. NCA	e.g. LFP, CoO, NaS, others	• Battery composition	• Sorting improvement • Cost reduction analytics
Initial processing	Discharge & dismantling	Discharge & dismantling	Discharge & dismantling	• Dismantling information incl. safety instructions • Manual for disassembly and dismantling	• Handling process improvement • Efficiency increase • Safety increase
Intermediate removal	Module, cell, auxiliary parts	Module, cell, auxiliary parts	Module, cell, auxiliary parts		
Material recovery	Material- and process-specific recycling	Material- and process-specific recycling	Material- and process-specific recycling		

See use case (F)

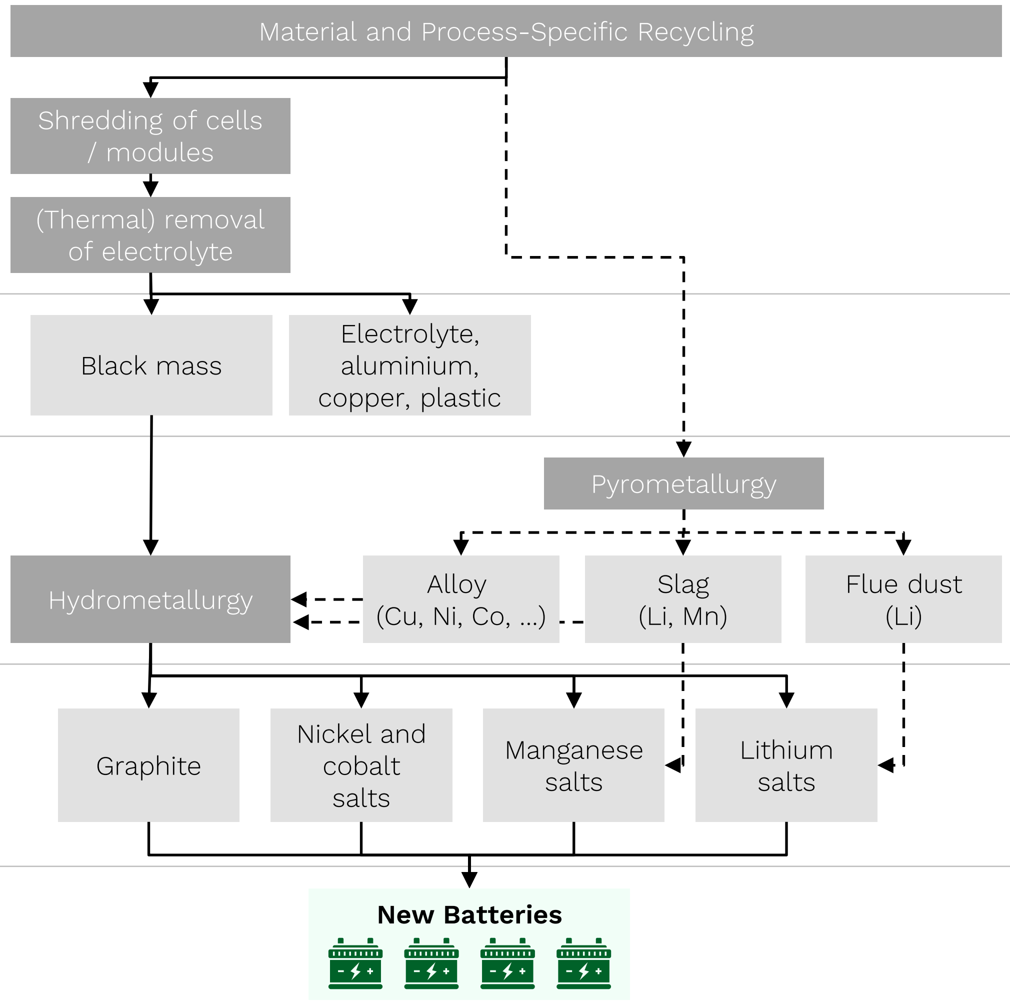
Main recycling treatment on next slide

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

1) Qualitative assessment

The pre-processing optimisations lead to improved material- and process-specific treatment processes

PROCESS VIEW



Process stage	Battery passport information	Value creation
Mechanical comminution & thermal pre-treatment	• Battery composition	• Improved mass balancing for recovery rates
Mechanical separation		
Refining	• Battery composition	• Higher yields due to lower contamination • Lower operating cost due to lower re-processing • Higher asset utilisation due to optimised feed
Recovery as precursor for battery materials	• Additional attribute "Recycled"	• Recycled material certificate tracing
Recycled precursors in new cell	• Additional attribute "Recycled"	• Reporting of recycled content

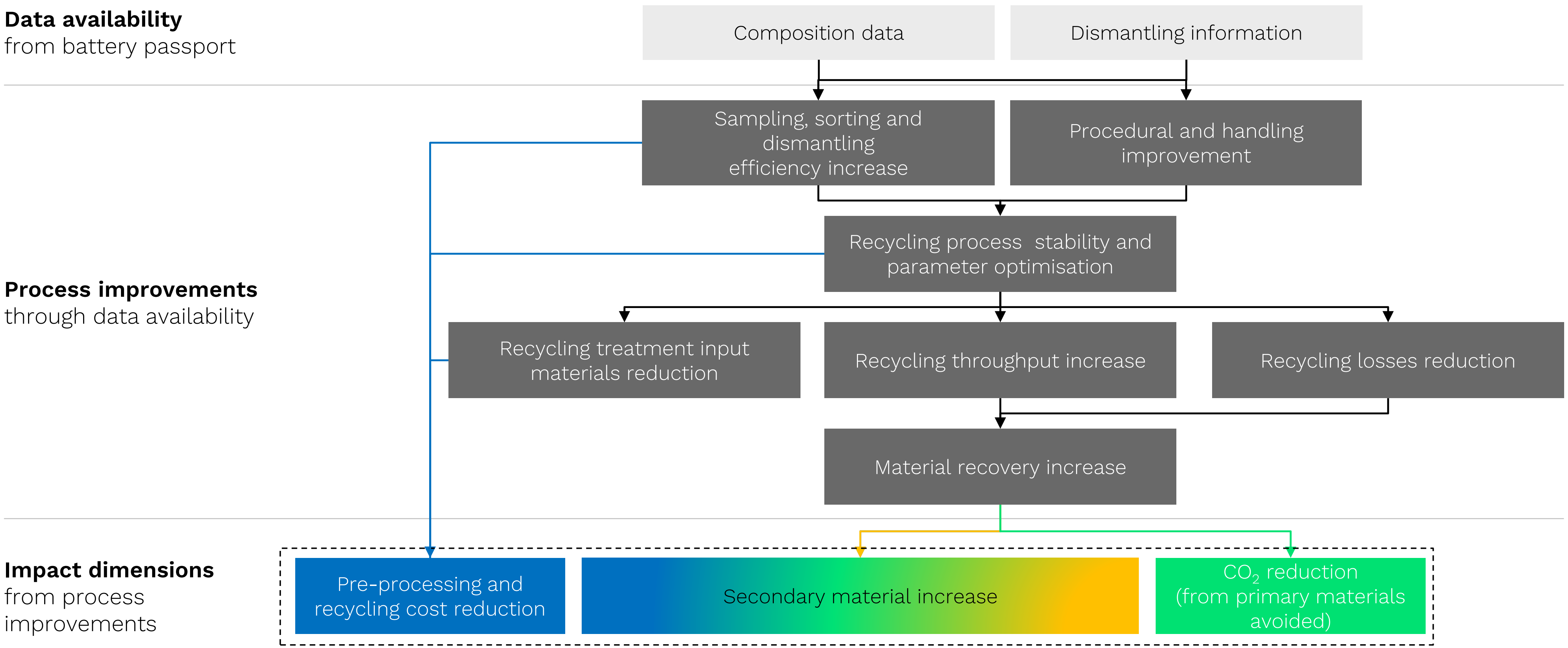
Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

1) Qualitative assessment

3 The recycling process improvements enabled by the battery passport data ultimately lead to economic, social and environmental impacts

Overview on process improvements and resulting impacts

Economic impact | Social impact | Environmental impact | Quantified



Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The quantification models recycling process improvements under a battery passport scenario for the mechanical-hydrometallurgical route

Quantification modelling approach

Scope

- Focus on a generic **mechanical-hydrometallurgical recycling route** (excl. procurement and logistics)
- Included: **cost** of pre-processing (sampling, discharge, dismantling), mechanical pre-treatment and hydrometallurgical treatment
- Based on the materials recovered, additionally available material related CO_2 reductions are modelled

Level of analysis

- Cost and revenue on process-level (micro): **single battery and recycling process**
- Material availability and associated CO_2 reduction on system-level (macro): **parameters aggregated on EU-level**

Scenarios

- **Baseline scenario:** for cost side reflecting different starting points of recyclers:
  - Information available via the seller of the waste battery (manufacturing waste battery)
  - No information available (EOL waste battery)
- **Battery passport scenario** (based on below improvement potentials)

Improvement potentials

Improvements with directly measurable impacts on baseline revenue and cost in percentage ranges

Modelled

√ Reduction of sampling and sorting costs
√ Reduction of dismantling costs
√ Reduction in recycling treatment costs
√ Increase in materials recovered

Not modelled, but additional benefits prevalent

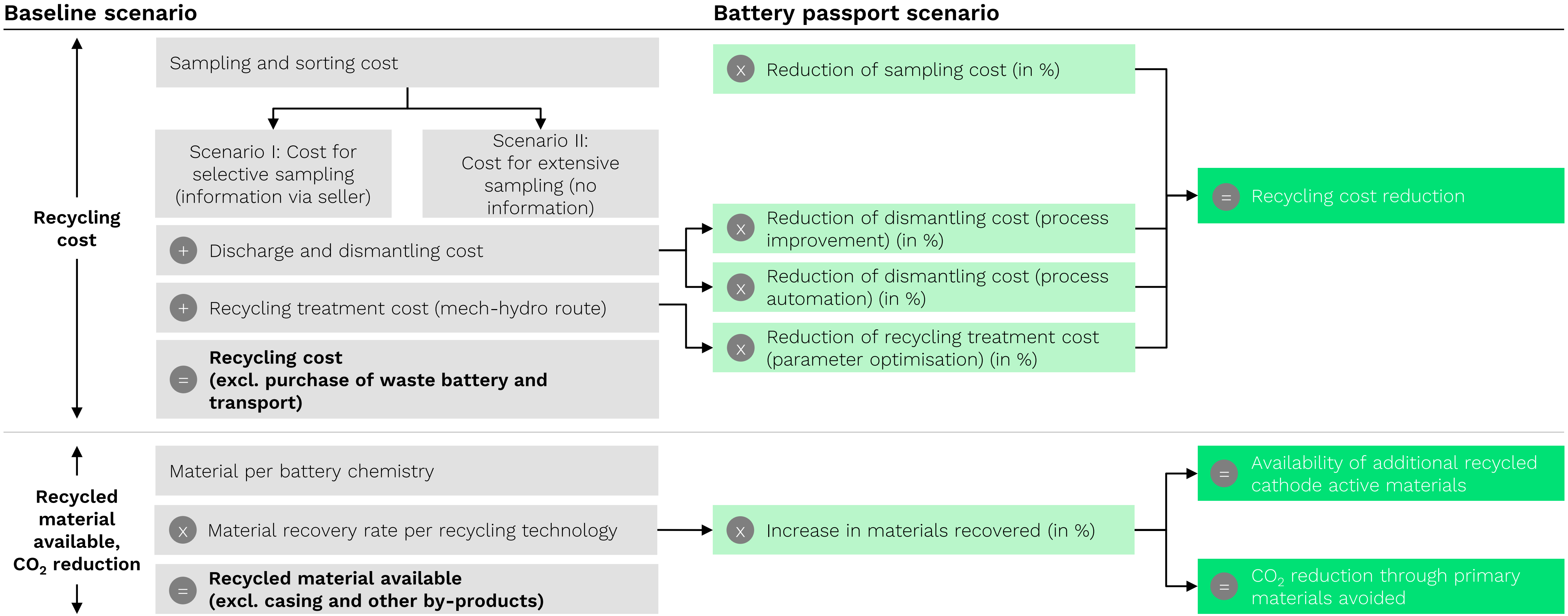
× Intermediate output specification/certification (black mass)
× Plant-level throughput increase through more efficient pre-processing
× CO_2 reductions from decreased contamination
× Procedural safety increase

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Under the battery passport scenario, recycling cost is reduced, revenue increased, availability of additional material ensured, and CO2 emissions lowered

SIMPLIFIED

Input | Improvement potentials | Outputs



See technical annex on slides 132-134 for main assumptions and their sources

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The improvements arise from process optimisations due to better information availability in pre-processing steps – the better the process integration, the higher the potentials

Lever description	Assumptions	Required conditions
Reduction of sampling cost • The availability of detailed battery composition and chemistry data leads to costly sampling procedures no longer being required. Thus, the batteries could be sorted cost-efficiently without risk of contaminating the feed with undesirable materials. Note that sampling will be required even with the battery passport but the amount of batteries sampled can be reduced. Over time, with increasing data accuracy and process integration, sampling efforts will likely gradually decrease.	↓ 50-80% sampling cost decrease	• Detailed battery composition data, incl. chemical specification and characteristics of battery materials • Information available on cell level
Reduction of dismantling cost • The availability of a detailed dismantling manual including e.g., format and position of screws or presence and type of glues leads to a reduction of time required and associated costs to disassemble the battery pack • The dismantling manual might be used to automatise parts dismantling process (particularly heavy and hazardous operations), further decreasing dismantling operation costs	↓ 20-40% dismantling cost decrease ↓ Additional 20-30% dismantling cost decrease	• Standardised format of dismantling information, in the best case as machine-readable dismantling manual • Exploded view of the battery, incl. format and depth of information • Automation equipment and software
Process control optimisation (reduction of treatment cost and increase of material recovery rate) • Homogenous battery recycling feedstock, that is pre-processed without contamination of undesired materials, would enable to improve the feed-in process (batch sequencing) and process parameters. Thus, recycling treatment process could be optimised in terms of controlling input parameter and sequencing. This reduces treatment costs as it prevents additional processing steps, which would be required to remove contaminants, and thus reduce losses in these steps. In turn, input the maximum process yield of the recycling process could be achieved	↓ 10-20% material and process cost decrease (hydromet. process) ↑ 1-2% material recovery rate increase (translates into material availability, and CO_2 reduction)	• Detailed battery composition data, including the chemical specification and characteristics of the battery materials, including electrolyte, glues and other elements potentially influencing the recycling process

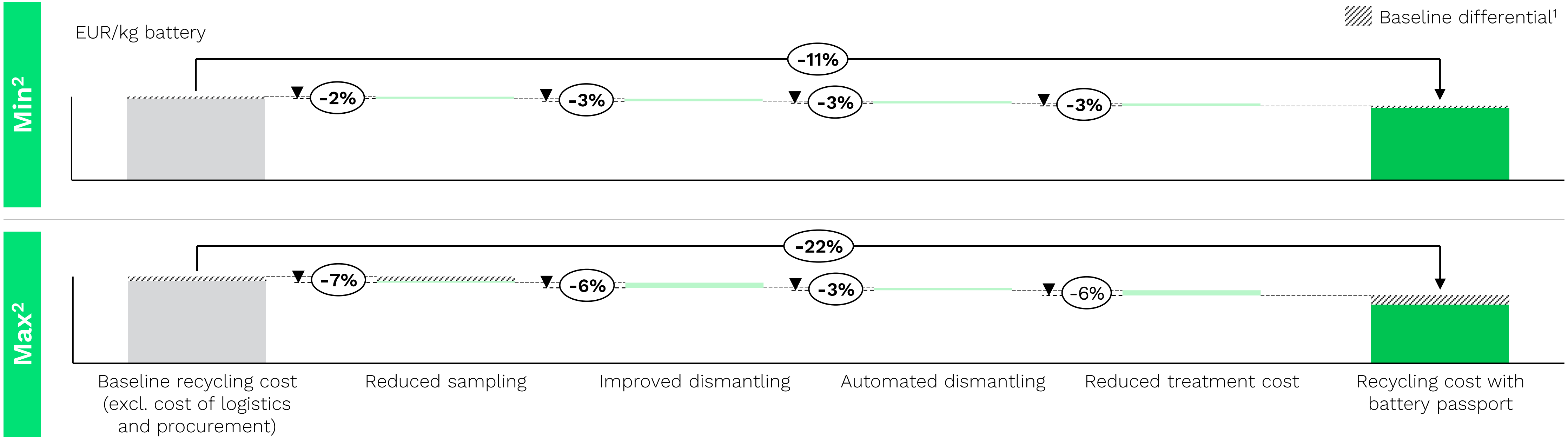
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

If recycling companies can leverage composition and dismantling data, recycling pre-processing and treatment cost could be reduced by ~ 10-20%

Micro perspective: Example High-Nickel NMC (622) EV Battery; generic mechanical-hydrometallurgical recycling cost (excl. cost of logistics and procurement)
Note that LFP battery recycling has different unit economics – however, the general pre-processing cost reduction levers could apply similarly.

Interactive visualisation

Battery Passport Scenario



Source: Systemiq analysis (2024) based on Argonne National Laboratory EverBatt (2023) and expert interviews, see technical annex on slides 130-132 for main assumptions and their sources

Baseline recycling cost:

Generic cost of recycling pre-treatment and mechanical-hydrometallurgical treatment excluding cost of procured EOL battery and logistics

Battery passport improvement potentials – information available can lead to operational cost improvements:

1) Reduction of sampling costs
2) Reduction of dismantling costs ("improved dismantling")
3) Additional reduction of dismantling costs ("automated dismantling")
4) Reduction of hydrometallurgical treatment costs (material and process costs)

1. Baseline differential describes the different starting points of recyclers with select information on composition being available or not (requiring intensive sampling).
2. Min and max consider the minimum and maximum values of the improvement potentials. These were incorporated to account for an uncertainty range reflecting the inherent uncertainty of future process improvements.

General note: The system boundary for the cost assessment is displayed on slides 59, 60 and 64.

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

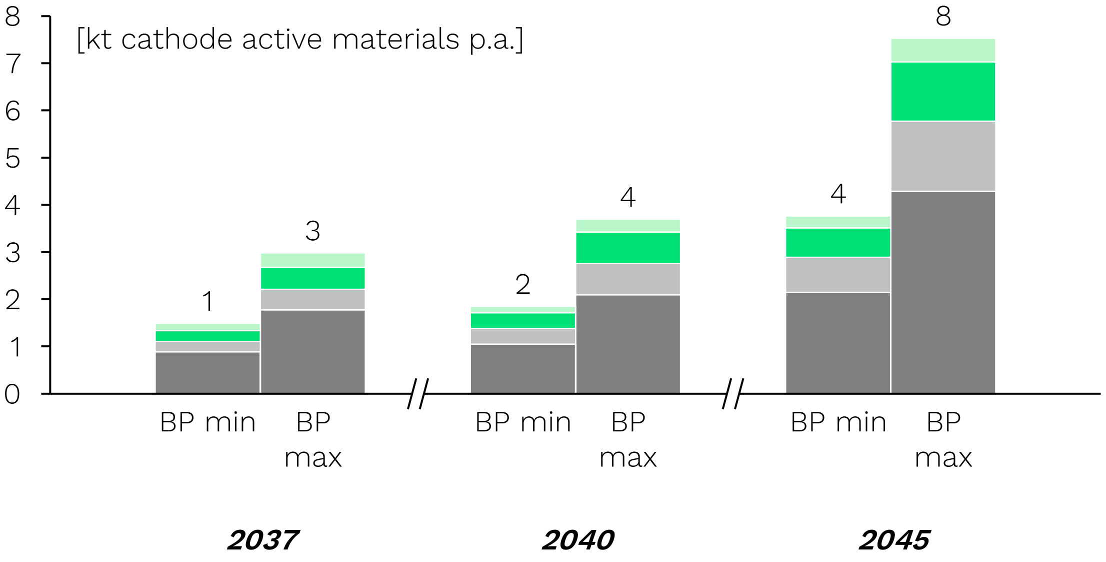
Improving the battery recycling process could lead to additional active materials recovered and associated carbon emissions reduced

Macro perspective: Materials additionally available on the EU market and corresponding CO_2 reduction

Cobalt | Lithium | Manganese | Nickel

Additional cathode active materials recovered

Due to slightly increased material recovery rates, we estimate that **European recyclers could recover between ~4-8 kilotons of additional cathode active materials each year**, starting 2045.

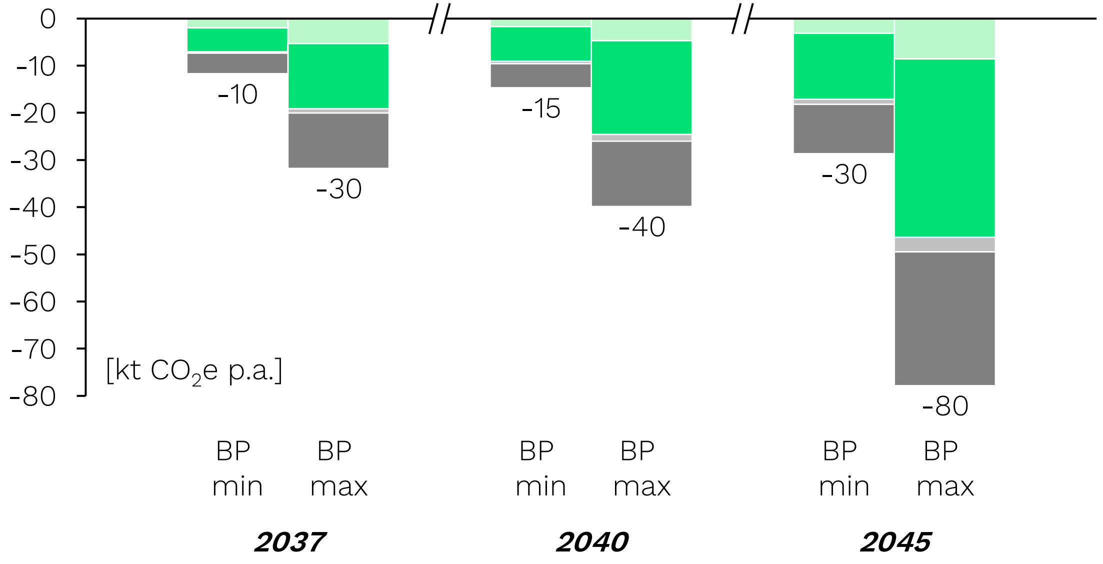


Source: Systemiq analysis (2024), active material intensity based on IEA (2023a) and Leader et al. (2019) see technical annex on slides 130-132 for main assumptions and their sources

Additionally recovered active materials could meet up to **1/4 of the difference between the technically possible maximum recovery rates and recovery rate targets** from the battery regulation.[1]

CO_2 reduction through primary materials avoided

Due to the additional secondary active materials available from increased material recovery, we estimate that **~ 30-80 kt CO_2 equivalents could be reduced each year**, starting 2045[2].



Source: Systemiq analysis (2024), emission factors based on Ecoinvent (2024), cut-off cumulative LCIA v.3.9.1, see technical annex on slides 130-132 for main assumptions and their sources

Additionally recovered secondary material **only marginally (<1%) reduces the carbon footprint associated with primary** active materials required to meet the demand for EV batteries.

1. Assuming max recovery rates for Ni, Co, Mn (98%) and Li (90%) as per Argonne National Laboratory EverBatt (2023). Reduction of contamination due to battery passport info yields additionally recovered materials, expressed as % of the difference between max technically possible recovery rates and battery regulation material recovery rate targets.
2. This graph does not include any general decarbonization pathways.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 4: Benefits

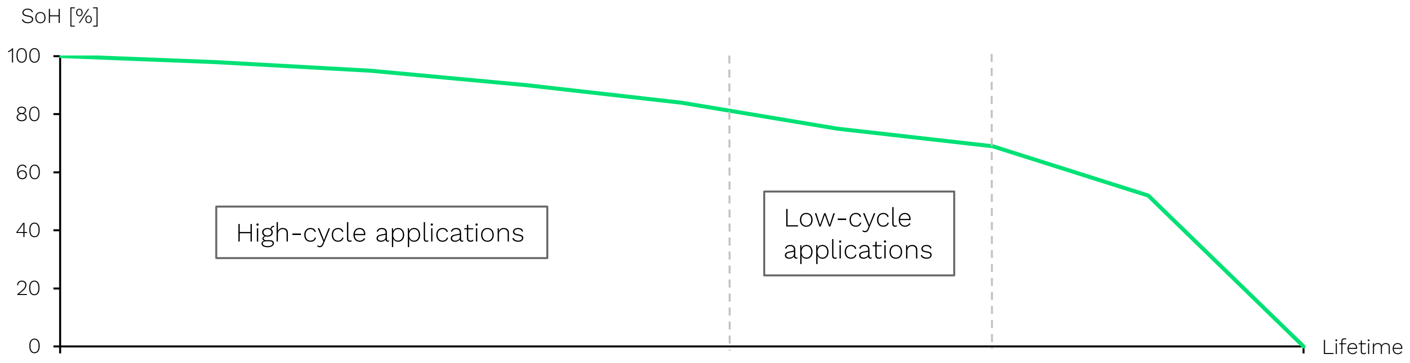
- Overview
- Direct use cases
  - Use case descriptions
  - Deep dive: (F) Simplified residual value determination
- Potential use cases
- Analysis on differences for industrial batteries

Introduction: EOL EV batteries still have around 70% remaining capacity and could be commercially attractive for a 2nd life, yet their technical suitability is difficult to estimate

The technical suitability of second-life batteries

- EV batteries usually **reach their end-of-life** in their first application due to decreasing range when they are **at an estimated state of health between 70-80%**
- **Depending on their usage profile**, they are still **suitable for different, less demanding applications** (high-cycle vs. low-cycle)
- However, a **single** state of health **value does not provide a reliable indication** on its future development, therefore more information is needed to make a qualified decision
- **Stationary storage systems** present the largest application area for second-life EV batteries
- As much larger volumes of EV batteries are being purchased, **second-life EV batteries** have the potential to maintain **commercial attractiveness for stationary storage**[1]

Suitability of batteries for different second-life applications depending on their state of health:



Adapted from: Bernhart et al. (2023)

Varying development of the state of health over the years:

Adapted from: Weng et al. (2023)

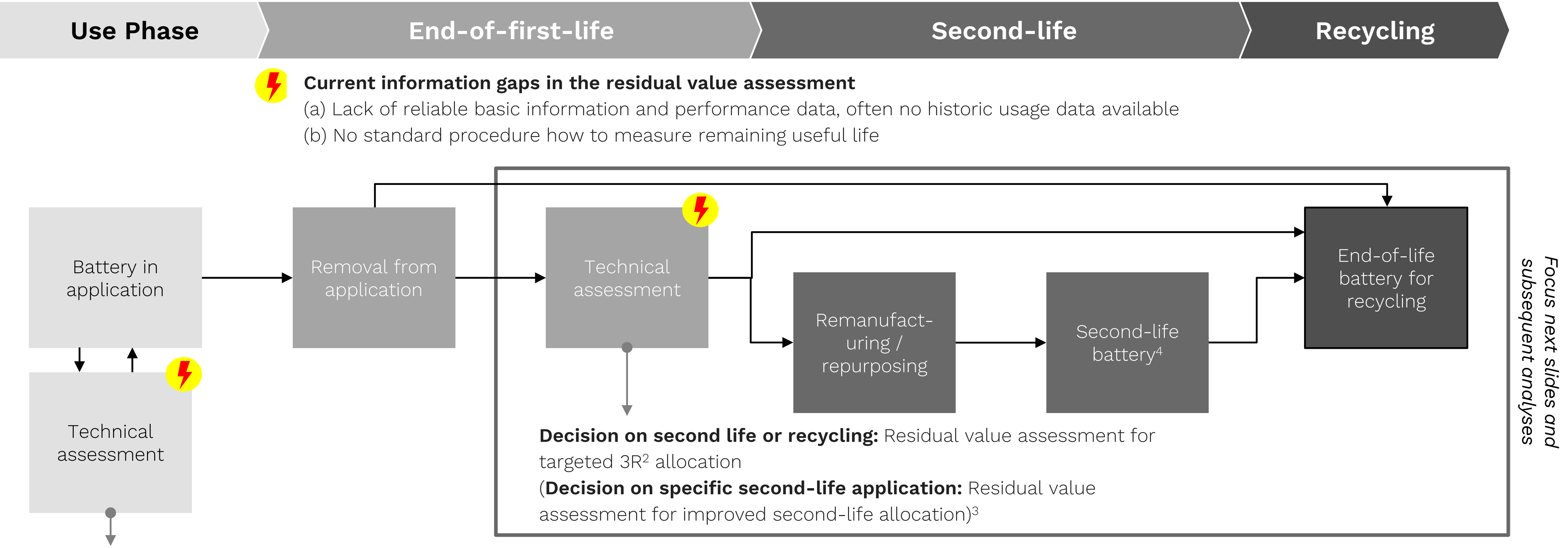
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

1. Kotak et al. (2021)

1 Currently, determining the residual value is challenging due to a lack of standard procedures, reliable basic information and historical performance data

EXEMPLARY[1]

Overview on the residual value determination process and current information gaps



Change of ownership: Residual value determination for reliable resale value
Repair / insurance: Residual value determination for improved repair cost estimations

1. No standard process exists today
2. Remanufacturing, repurposing or recycling
3. Specific 2nd life application likely already included in decision on 2nd life or recycling
4. Additional tests, e.g. State of Charge/Open Circuit Voltage testing, are needed for BMS recalibration. For safety and guarantee purposes, further tests and certifications are required, e.g. the current standard UL-1974

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

2 Data attributes available through the battery passport offer improvement potentials by reducing the need for technical tests and improving the accuracy of the assessment

	Data attributes[1]		Improvement potentials enabled by data attributes	Specification requirements
Dynamic	**Capacity and energy** • Rated capacity • Capacity fade • State of certified energy (SOCE)	**Internal Resistance** • Current internal resistance • Internal resistance increase	*Quantified* 1. Reduce effort for initial technical tests (consisting of capacity and energy testing, internal resistance testing) 2. Increase number of batteries going into second life	• Should contain several data points, 6 to 12 months with a monthly resolution[2] • Dynamic data need to be actively measured and logged (e.g. by the BMS) during the battery lifetime • All information should be accessible for modules as the batteries are usually transferred to their second-life in modules
Dynamic	**Expected lifetime** • Expected lifetime in cycles and calendar years • Current number of (full) charging and discharging cycles **Negative events** • Accidents	**Power Capability** • Original power capability • Power fade **Temperature conditions** • Time spent charging during extreme temperatures • Time spent in extreme temperatures	3. Improve accuracy of assessment of suitability for second life and safety risks 4. Streamline allocation to suitable second-life application (high-cycle vs. low-cycle applications)	
Static	**Battery composition** • Battery chemistry		5. Facilitate the calculation for economically more viable route (re-use/repurpose vs. recycling) by considering the material value of the battery	

1. As deep dive focuses on EV batteries, only those required for EVs listed
2. Such that a gradient of State of certified energy (SOCE) or capacity fade could be derived, to detect the "knee point" (where the state of health of the battery starts declining rapidly)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

1) Qualitative assessment

❸ The residual value determination improvements enabled by the battery passport data lead to economic, social and environmental benefits

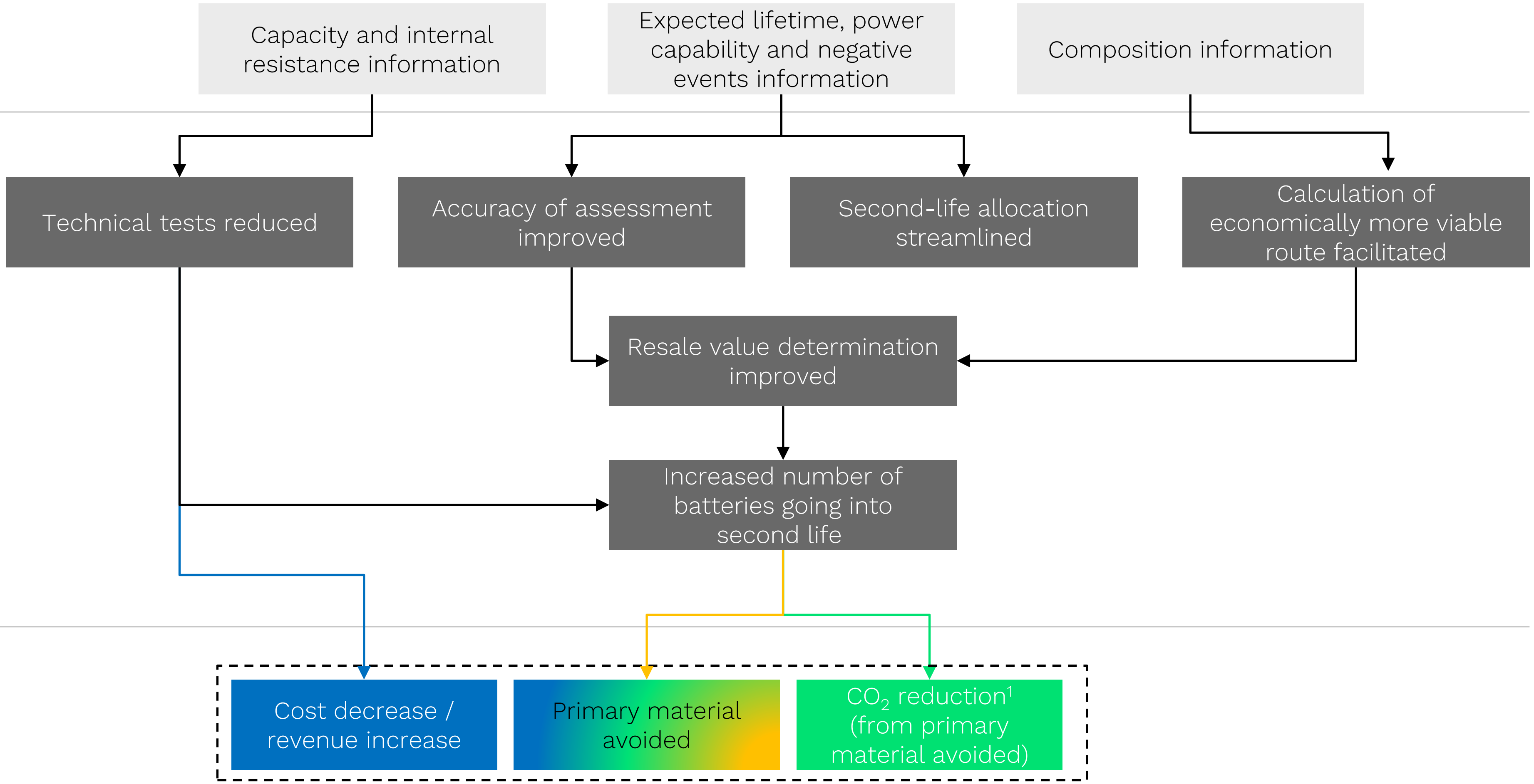
Overview on process improvements and resulting impacts

Economic impact | Social impact | Environmental impact | Quantified

Data availability from battery passport

Process improvements through data availability

Impact dimensions from process improvements



1. For more information, please refer to the excurses on slide 78 as well as the quantification on slides 74-79 and model assumptions in the annex (slides 135-137).

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The quantification models the residual value determination process for three different battery sourcing scenarios and respective information availability

Quantification modelling approach

Scope

- Battery application: First life electric passenger vehicles (BEV), second-life: stationary battery energy storage system (SBESS)
- Geography: Europe (EU27, Norway, Iceland, Switzerland and United Kingdom)
- Timeframe: 2037-2045 (with the battery passport being required from Feb 2027, the respective batteries will reach the end of their first life in 2037 with an average lifetime of 10 years assumed)

Level of analysis

- Cost and revenue on process-level (micro): **single battery/module for procurement incl. technical testing costs**
- Primary material avoided and associated CO_2 reduction on system-level (macro): **parameters aggregated on EU-level**

Scenarios

- **Baseline scenarios:**
  - Inhouse sourcing: battery information available via BMS (e.g. first life OEM is also second-life operator)
  - Direct sourcing: some battery information provided (e.g. partnership with OEM)
  - Indirect sourcing: no reliable battery information available (e.g. open marketplace)
- **Battery passport scenario** (based on below improvement potentials)

Improvement potentials

Improvements with directly measurable impacts on baseline costs and material avoidance

Modelled

√ Testing effort reduced

√ Increase in batteries going into second-life

Not modelled, but additional benefits prevalent

× Accuracy of assessment increased

× Allocation to suitable second-life application streamlined

× Calculation for economically more viable route facilitated

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Under the battery passport scenario, technical testing costs are reduced, and the batteries re-used for a second-life application increased

SIMPLIFIED — Input — Improvement potentials — Outputs

Baseline scenario

Residual value determination cost

- Average price of second-life battery
- + Technical assessment testing costs
  - Scenario I: Inhouse sourcing
  - Scenario II: Direct sourcing
  - Scenario III: Indirect sourcing
- = **Procurement including technical testing costs**

Primary material avoided and CO2 reduction

- EV batteries re-used for second-life application
- x Remaining capacity
- x Active materials needed for new LFP batteries
- = **Primary active material avoided**

Battery passport scenario

- – Reduction of technical testing costs → = Reduction of procurement including technical testing costs
- x Increase in batteries re-used for second-life application → = Increase in avoided primary active materials[1]
  - x CO_2 footprint of primary raw materials
  - = CO_2 reduction through increase in avoided primary materials

1. Average LFP battery for stationary storage assumed

See technical annex on slides 135-137 for main assumptions and their sources

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The battery passport could lead to a reduction of technical testing costs and thereby increase the number of batteries going into a second-life application

Lever description	Assumptions	Required conditions
Reduction of technical testing costs • Access to detailed (historical) information on battery capacity and energy as well as internal resistance could reduce costs associated with technical tests required to assess battery suitability for a second-life application, especially for independent second- life operators that do not already have access to this information through the BMS.	↓ 100% reduction of capacity and energy testing ↓ 100% reduction of internal resistance testing	• Standardised and reliable performance and durability data on the battery passport that are accepted in second-life certification procedures
Increase in batteries going into a second-life application • We estimate that the reduction of technical testing costs could lead to an increase in batteries going into a second-life application as this supports their economic competitiveness compared to new batteries.	↓ 0.4 % - 3.4 %[1] more batteries going into a second-life application	• End-of-life EV batteries substituting new LFP batteries for stationary battery energy storage

1. Assumption that the number of batteries going into second-life rises proportionally to the decrease of the testing costs proportionally to the decrease of the price

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The cost reduction depends on the testing needs in the different scenarios; we estimate that ~ 2-10% of the procurement including technical testing costs could be reduced

Micro perspective: Baseline procurement incl. technical testing costs for three different battery sourcing scenarios and reduction enabled by the battery passport

Interactive visualisation

Inhouse sourcing

e.g. first life OEM same as second-life operator (All information available)

- Share of modules tested[1]: 0%

Min[2]

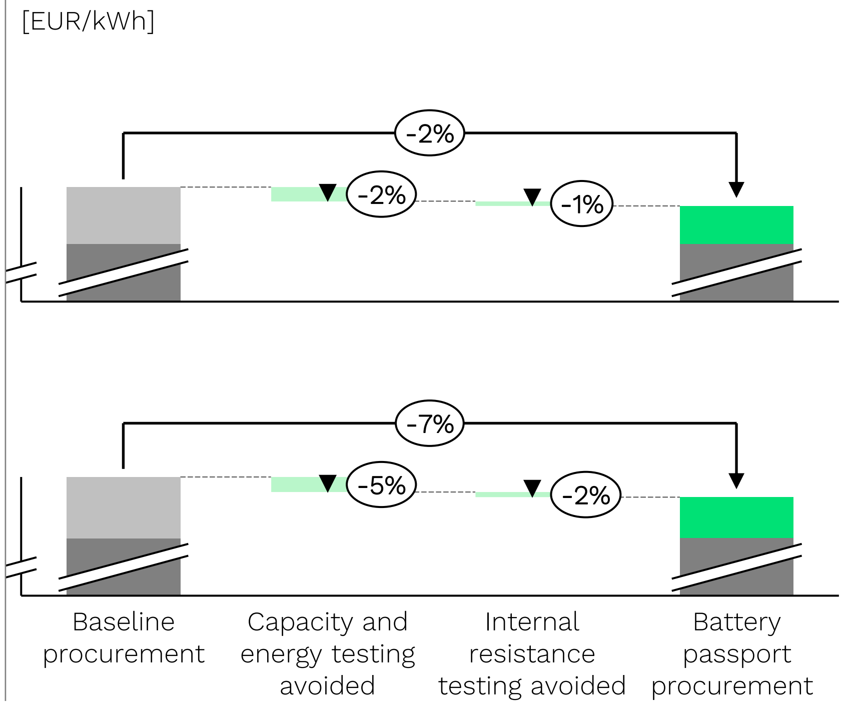
Max[2]

No testing costs, therefore, no improvement potential

Direct sourcing

e.g. partnership of second-life operator with OEM (Information partially available)

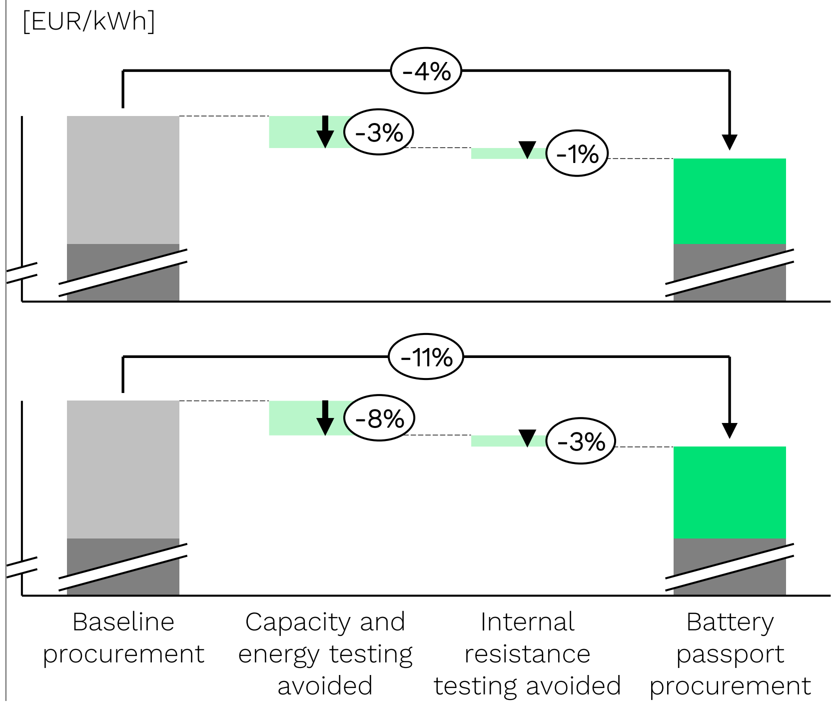
- Share of modules tested[1]: 1%



Indirect sourcing

e.g. open marketplace (No (reliable) information available)

- Share of modules tested[1]: 2%



- Technical testing costs
- Avoided technical testing costs
- Price of second life battery

1. From acquired EOL batteries
2. Min refers to minimum testing costs with one temperature tested, max refers to maximum testing costs with three temperatures tested

Source: Systemiq analysis (2024) based on expert interviews and Global Sustainable Electricity Partnership (2021) see technical annex on slides 133-135 for main assumptions and their sources

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Excursus: Though innovations lead to reduced material demand and increased energy efficiencies, repurposed batteries are more environmentally beneficial than new ones

Is a second life always more sustainable?

The environmental footprint of batteries varies depending on their chemistry

It needs to be considered what type of chemistry is being substituted.

Furthermore, battery impacts could be mitigated by:

(a) Extending their lifespan through reusing and repurposing

(b) Innovations reducing material demand and increasing efficiency

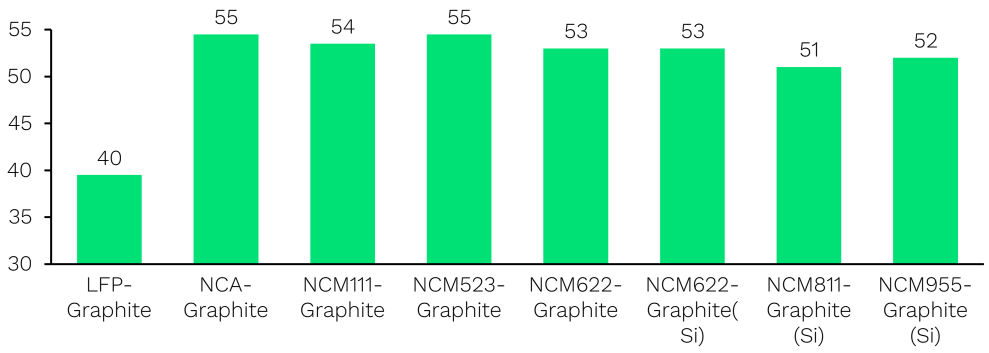
A recent study[1] investigates whether technological innovations may alter the current waste hierarchy, emphasising repurposing over recycling, as this could enable retired batteries to promptly supply constituent materials for use in low-material demand, higher-performing batteries:

- Life Cycle Assessment of 24 scenarios in total, covering changes in cathode chemistry, anode material, and recycled content for new and retired electric vehicle lithium-ion batteries
- Examines the environmental impact of two end-of-life management routes:
  a) Recycling the battery immediately after its first use to create a new, less material-intensive battery
  b) Repurposing the battery for stationary storage followed by recycling

Repurposing end-of-life lithium-ion batteries is generally more environmentally beneficial than manufacturing a new battery for the same stationary use. However, recycling immediately could be preferable in certain scenarios, especially with decreased cycling efficiency.

Cradle-to-gate emissions of cell production in Europe by battery chemistry in 2020

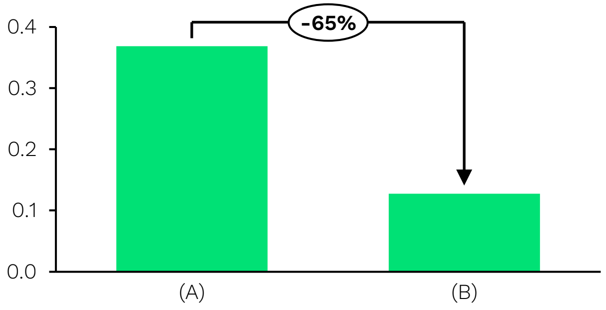
[kg CO2 eq/kWh capacity]



Adapted from Xu et al. (2022)

Comparison of cradle-to-grave emissions of one scenario

[kg CO_2 eq/1 kWh cycled]



Adapted from Dunn et al. (2023)

Supported by: Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

1. Dunn et al. (2023)

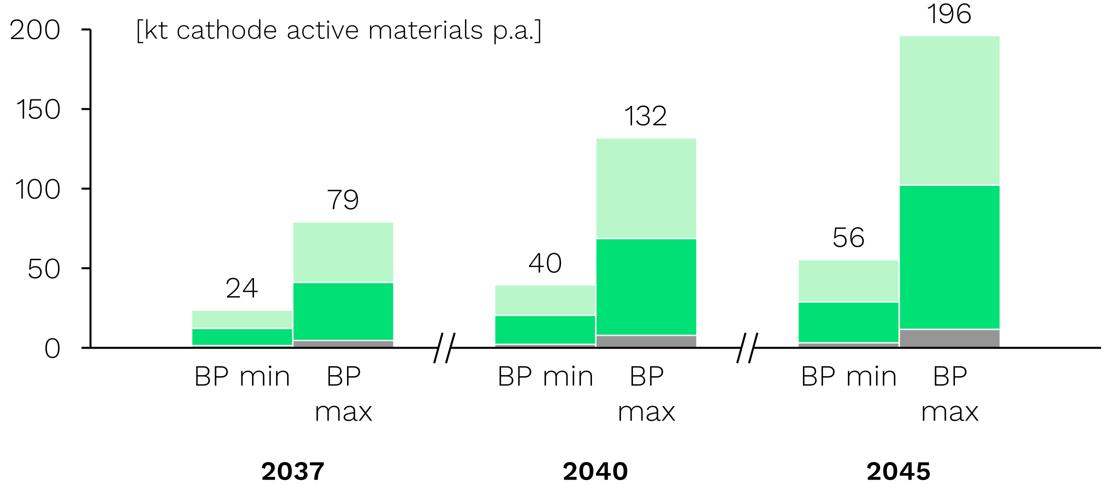
The estimated increase in batteries going into a second-life could fulfil ~ 6-20% of demand for stationary battery energy storage and reduce carbon emissions

Macro perspective: Primary raw materials avoided and CO2 reduction through primary materials avoided on the European market

Graphite Iron Lithium

Primary raw material avoided

Due to the decrease of technical testing costs, **we estimate a proportional increase in batteries going into second-life of 0.4-3.4%**, this **leads to ~ 60-200 kt of primary cathode active materials that could be avoided** annually by 2045 when these batteries substitute LFP batteries (e.g. for stationary battery energy storage).

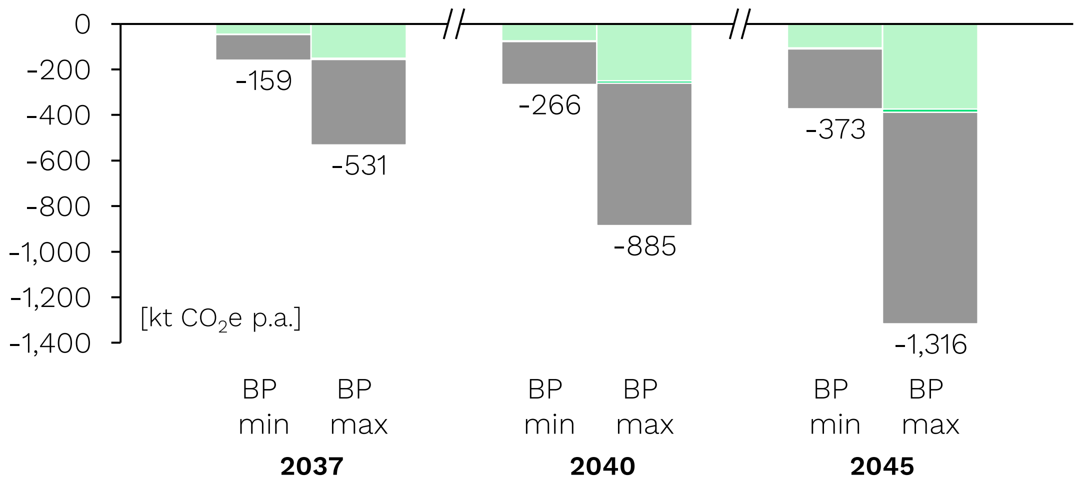


Source: Systemiq analysis (2024), active material intensity based on IEA (2023a) and Leader et al. (2019) see technical annex on slides 133-135 for main assumptions and their sources

This could fulfil ~ 6-20 % of demand for stationary battery energy storage in Europe.[1]

CO2 reduction through primary materials avoided

Based on the primary raw materials avoided, we estimate that **between ~ 370 and 1300 kt of CO_2 eq. could be reduced** annually by 2045.



Source: Systemiq analysis (2024), emission factors based on Ecoinvent (2024), cut-off cumulative LCIA v.3.91.1, see technical annex on slides 133-135 for main assumptions and their sources

This **reduction is mainly caused by avoided primary lithium**, which has by far the highest carbon footprint of the three active materials in LFP batteries.

1. Assuming max recovery rates for Ni, Co, Mn (98%) and Li (90%) as per Argonne National Laboratory EverBatt (2023). Reduction of contamination due to battery passport info yields additionally recovered materials, expressed as % of the difference between max technically possible recovery rates and battery regulation material recovery rate targets.
2. This graph does not include any general decarbonization pathways.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
- Analysis on differences for industrial batteries

Potential use cases could be enabled provided certain conditions are in place which would go beyond current regulatory requirements

Conditions required beyond regulatory requirements…	…to enable potential use cases
Application of traceability systems for data collection The Battery Regulation and passport data requirements increase the need for reliable and credible data in upstream value chains. This could be enabled by gathering the data via traceability systems which, when complementing battery passport solutions, could unlock another use case through optimising data processing and use.	(H) Efficient data exchange and reporting based on upstream traceability
Integration in regulated downstream processes and systems To ensure battery collection, additional information on the downstream status as well as integration into official processes such as export control are needed. This would unlock another use case.	(I) Increased end-of-life collection
Aggregation of data from different passports Aggregation of data from different battery passports, solved through an EU Commission-provided infrastructure or managed by specialised service providers, could provide additional information on market or organisation level and thereby unlock further use cases.	(J) Industry benchmarking (M) Accurate market overview (L) Informed policy design

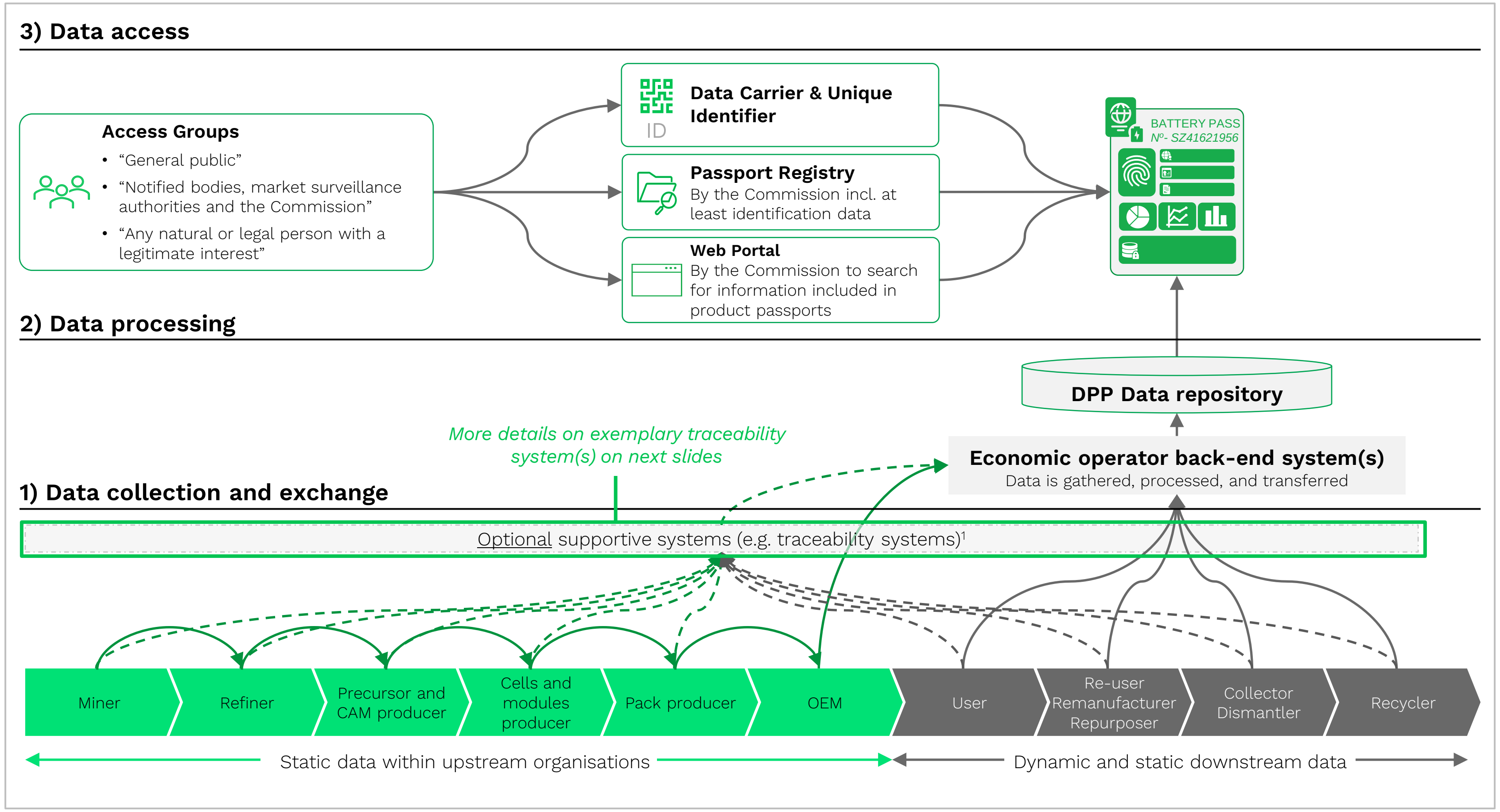
Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
  - Enabled by application of traceability systems for data collection
  - Enabled by integration in regulated downstream processes
  - Enabled by aggregation of data from different passports
- Analysis on differences for industrial batteries

The Battery Regulation and battery passport data requirements increase the need for reliable, trustworthy, and consistent data flows in upstream value chains

- The EU battery passport **requires information** from the upstream value chain
- Today, the **upstream value chain is often opaque** to a battery manufacturer
- For ESG metrics, the battery manufacturer must **rely on claims of direct suppliers**
- Article 49 of the Battery Regulation defines the establishment and operation of a **system of control and transparency**, which could be realised with a traceability system
- The application of traceability systems fosters the **digitalisation** of the complete upstream value chain
- This leads to **higher reliability** of data gathering since data will be collected automatically
- Based on all information, cross-referencing (e.g. mass-balance) is possible that allows further **verification and validation** of data that leads to higher data quality
- The additional information allows economic operators **better assessments of potential risks** which leads to better risk mitigation strategies and finally to more resilient supply chains

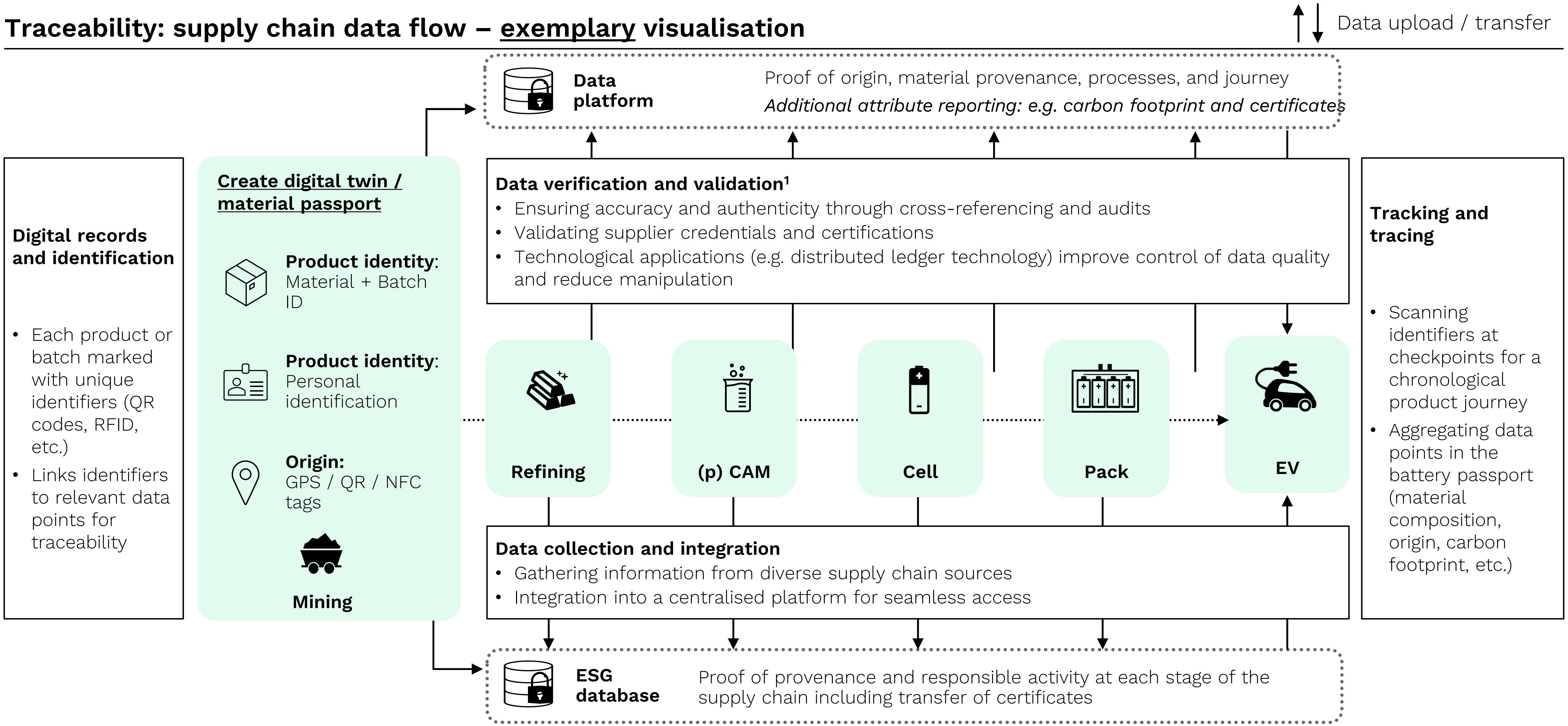


1. Traceability systems are optional supportive systems for the collection of battery passport data along the supply chain. Note that other means to collect supply chain data may be applied for achieving EU battery regulation compliance (e.g. reverse reporting).

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Traceability systems could enable this upstream data collection verifiably and could complement battery passport solutions, if data and systems are interoperable

Traceability: supply chain data flow – exemplary visualisation



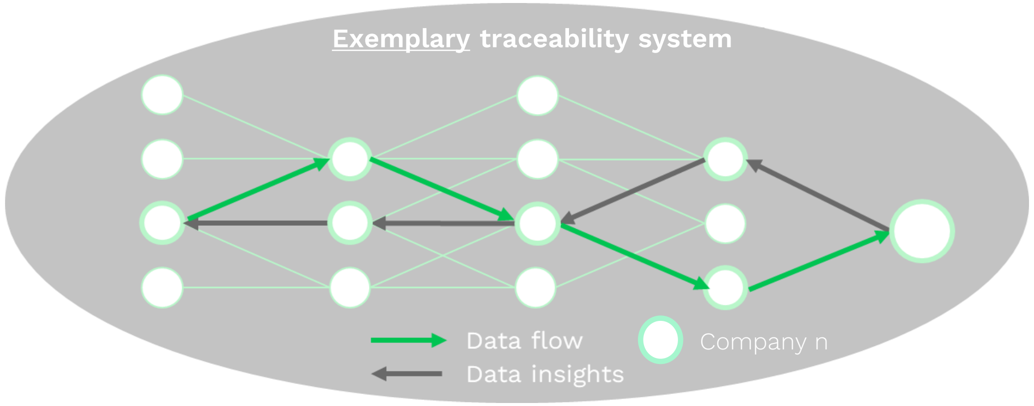
1. Frameworks for auditing, procedures and standards are required for all steps of the upstream supply chain.
General note: Traceability systems face technical challenges similar to the battery passport. Please refer to the Battery Passport Technical Guidance for challenges on data ownership, sensitivity and interoperability.

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Upstream data collection through traceability and other data exchange systems could unlock a potential passport use case through optimising data processing and use

A traceability system enables the productive use of data by facilitating data collection and verification

HOW



Purposes and configurations of traceability systems

- **Digital chain of custody**: Guarantees correct accounting and corroborates a link between ingoing content, e.g. "sustainable" "recycled" by harmonised definitions, and the final outgoing product
- **Carbon tracing**: Enables standardised exchange of carbon emissions data between organisations and accounting solutions
- **Geographical material and component tracking**: Traces materials and components along the value chain up to the point of provenance

WHY

Mechanisms unlocking benefits

- Improving company-specific data availability in upstream supply chains
- Creating credibility and reliability of data through verification procedures
- Establishing systems for peer-to-peer data exchange and data relationships
- Connecting upstream data to company systems (e.g. procurement ERPs)
- Big data analytics across supply chain indicators and attributes

Benefits of data collection and exchange

- Trustworthy and reliable interorganisational reporting of data and certificates
- Reduction of transaction costs for data collection, aggregation, and verification
- Company-specific identification of ESG metrics and data
- Risk mitigation and supply chain resilience (advanced insights into supply chains)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

H Efficient data exchange and reporting based on upstream[1] traceability: traceability systems could improve the reliability and efficiency of data reporting

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining → Refining → Precursor and CAM production → Cells and modules manufacturing → Pack assembly and integration → Usage → Re-use Remanufacture Repurpose → Collection → Recycling

Direct use case / Potential use case / Not applicable

Battery passport user: Business | Authority | Private consumer

1 Situation without battery passport

Companies need information about the (sustainability of the) product to comply with regulatory requirements, mitigate risks, and meet market and consumer preferences. This information needs to be requested and collected and is often not available in an interoperable, comparable and certified format.

2 Improvements with battery passport

Data attributes from the upstream supply chain need to be gathered and digitised for the battery passport:

- Supply chain due diligence (due diligence report), traceability or chain of custody required as per Article 49 1(d)
- Carbon footprint (in total and share per life cycle stage)
- Circularity and resource efficiency (recycled content shares)

Collecting carbon footprint and circularity data via traceability systems can enhance credibility and reliability through digital certification and verification procedures. Interconnecting upstream traceability systems to the battery passport facilitates efficient and dynamic data reporting by enabling the exchange of company-specific data within supply chains.

3 Benefits (along impact dimensions)

Economic

- Data reporting and exchange systems could increase the efficiency of the data collection process and thus reduce cost of reporting (compared to manual reporting)
- Emerging data ecosystems that span across the supply chain could enable supplier selection and engagement strategies based on more granular, company-specific data
- Leveraging upstream traceability systems increases the quality and integrity of shared data through embedded verification procedures

Environmental

- Company-specific and dynamic ESG information in a digital and interoperable format could support identifying hotspots and actively engage with their suppliers to reduce carbon emissions and develop material circularity strategies
- Data exchange systems and benchmarking across the supply chain enable supplier engagement strategies and supplier selection decisions
- Tracing recycled materials (e.g. through chain of custody certificates) increase the reliability of associated claims

Social

- Traceability systems (e.g. chain of custody systems) could lead to more granular transparency on the social sustainability of suppliers to manage and mitigate social risks
- Certification and auditing along the supply chain improves the credibility of social sustainability claims

Applicability to industrial batteries[2]: Equally applicable for all industrial batteries

1. Upstream includes the procurement of recycled materials, i.e. embedding recycled content traceability from recycler to CAM producer, the battery carbon footprint, and supply chain due diligence requirements..
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
  - Enabled by application of traceability systems for data collection
  - Enabled by integration in regulated downstream processes
  - Enabled by aggregation of data from different passports
- Analysis on differences for industrial batteries

The battery passport could offer a solution to solve the difficulties in tracking the whereabouts of batteries downstream and thereby increase collection

Today it is difficult to track the whereabouts of batteries

- The battery passport as required by the EU Battery Regulation does not require any information on when and where a battery was recycled or if it was exported
- The regulation specifies reporting requirements for producers and waste management operators on the number of batteries placed on the market as well as treated to the member states authorities, which then report to the Commission
- However, there is no direct link between the reported quantities of batteries placed on the market and treated,[1] potentially leading to discrepancies, especially when batteries are sold in one member state and recycled or exported in another
- In existing tools that monitor the raw materials in the battery value chain, such as the RMIS developed by the JRC, information on the whereabouts within the member states are not yet included, and exports are assumed to be zero as they cannot be quantified
- To ensure absolute collection, it is essential to have precise information about the location and quantities that could be collected

The battery passport could provide a solution

Certain conditions are needed

- Additional data attributes to be able to track the downstream status of the battery (recording export and recycling locations)
- Automated integration of the battery passport in regulated downstream processes such as customs control for exports, as already proposed by the ESPR[2] yet mainly targeting imports, and market surveillance processes
- Integration into required administrative procedures, such as vehicle de-registration for the example of EV batteries as the largest amount, yet a similar solution still needs to be found for industrial and LMT batteries where no de-registration is required

The battery passport could also be incorporated in future reviews and improvements of waste legislation

1. For more information on reporting to authorities and battery status, please refer to the Battery Pass consortium Content Guidance (2023a, p. 40, p. 68)
2. Council of the European Union (2023) (ESPR, Art. 13) proposes an interconnection of the DPP registry with the EU Customs Single Window Certificates Exchange enabling automated exchange

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

I Increased end-of-life collection: Additional information could aid in preventing battery leakage by leveraging the passport for export control and market surveillance

Level of impact: No | Low | Middle | High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case | Potential use case | Not applicable

Battery passport user: Business | **Authority** | Private consumer

1 Situation without battery passport

Currently, around a third of passenger vehicles leaving European roads are in "unknown whereabouts" due to illegal or opaque exports or undocumented EOL treatment. With an increasing share of EVs in the European fleet, this poses a significant risk of losing valuable battery materials from the European market (battery leakage).

2 Improvements with battery passport

This use case through the integration of the battery passport into regulated downstream processes under the following conditions:

- Integration of battery passport into de-registration, export control and market surveillance processes
- Using the information on the state of health to support the differentiation between end-of-life vehicle and used vehicle[1]
- Reporting of additional information in the passport:
  - Amend "battery status" by "exported" and "recycled"
  - Indicate the "name of authenticated exporter" and "name of authorised recycling facility" as well as the "battery owner"
  - Add the "date of export" and "date of recycling treatment"

3 Benefits (along impact dimensions)

Leveraging the battery passport for formalising de-registration, export control and market surveillance could lead to:

Economic (impact: High)

- Increased material availability in the regional market which leads to higher revenues for recycling companies
- Improved oversight that contributes to a level playing field for EU-based battery recyclers
- Increased availability of secondary material from the regional market which reduces cost for battery producers vs importing primary material from outside the EU

Environmental (impact: High)

- A higher and formal collection of batteries that increases the regional availability of material for recycling and thereby reduces the environmental impact since replacing primary by secondary material and avoiding inferior EOL treatment
- Fewer exports to regions with a lack of proper waste management, thus reducing local contamination

Social (impact: Middle)

- A reduction of illegal and inferior recycling practices, that often involve unsafe methods like open burning, therefore enhancing public safety and health

Applicability to industrial batteries[2]: – Less applicable for all industrial batteries

1. Only possible for EV batteries, no similar process exists for LMT or industrial batteries yet
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
  - Enabled by application of traceability systems for data collection
  - Enabled by integration in regulated downstream processes
    - Deep Dive: (I) Increased end-of-life collection
  - Enabled by aggregation of data from different passports
- Analysis on differences for industrial batteries

1) Qualitative assessment

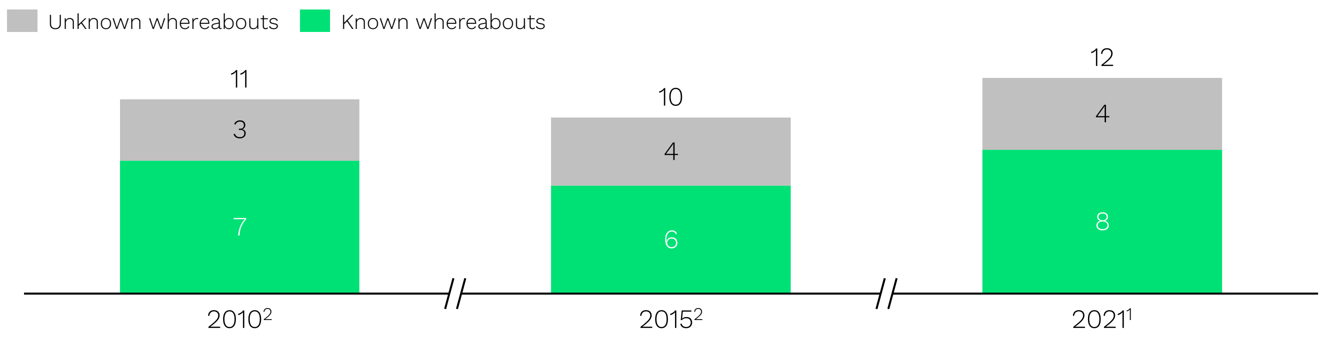
Introduction: Vehicles (incl. their batteries) leaving Europe with unknown whereabouts are an environmental and safety threat and a waste of resources particularly for recycling

EU vehicles with unknown whereabouts

- Around a third of passenger vehicles leaving European roads are in "unknown whereabouts" (unclarity about whether the vehicle was handled by an (un) authorised recycling facility or exported[1])
- The reasons range from:
  - Illegal treatment and export mainly driven by profits from sale of spare parts and metals[2]
  - Unclear differentiation between used vehicles and end-of-life vehicles leading to illegal exports of end-of-life vehicles
  - Undocumented treatment in authorised facilities
- The impact is substantial incl.:
  - Environmental pollution
  - Safety hazard
  - Resource waste
  - Lack of material available for recycling

Number of passenger vehicles leaving European roads by whereabout status[1,2]

in mn



Relevance for electric vehicle (EV) batteries

- Missing EVs incl. their batteries result in regional loss of critical materials, such as cobalt, nickel, lithium, manganese and graphite
- Waste batteries may become a burden in markets without the capacity and infrastructure for safe and effective treatment[3]

Issue of illegal exports and dismantling is similar for other battery types (e.g. waste from electrical and electronic equipment)[4]

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

1. Heinrich Böll Stiftung (2021)
2. Umweltbundesamt (2020)
3. UNEP (2023)
4. BAN (2018)

Excursus: The draft revision of the End-of-Life Vehicle Directive aims to tackle the issue of unknown whereabouts – the battery passport could support this objective

Draft revision of the End-of-Life Vehicle Directive ("Circular Vehicles Regulation")[1]

Measures to reduce unknown whereabouts

- Circular design: Call for a **circularity vehicle passport**
- Increased and smarter collection:
  - Harmonised reporting for vehicle registration (incl. de- and re-registration) in the EU via the "MOVE-HUB" electronic system
  - Dismantlers and recyclers' obligations to check and report on end-of-life vehicles (ELV) and issue a certificate of destruction (CoD)[2]
  - Enforceable guidelines to distinguish between ELVs and used vehicles
  - Tighter export requirements for used vehicles (roadworthiness checks) to prevent illegal export of ELVs
  - Enhanced collection of ELVs, with obligations on vehicle owners to deliver their vehicle to an authorised treatment facility
- Increased responsibility: Reinforced extended producer responsibility (for automotive OEM)

How does the battery passport relate to this?

- The battery passport is already **required around 5-7 years** before the circularity vehicle passport will be implemented
- It **concerns the individual battery** that could be treated or exported **independent of the vehicle** and therefore needs to be documented separately
- Circularity information required by the battery passport could serve as a **blueprint for the circularity vehicle passport**
- The battery passport of an EV battery should ideally be **connected to the circularity vehicle passport** for as long as it is in the vehicle and support in confirming the roadworthiness of an EV
- The scope of the battery passport goes beyond EVs incl. **other applications** (industrial batteries > 2kWh and LMT batteries)

1. European Commission (2023b)
2. A certificate of destruction is required to officially document the treatment of an ELV, thus ensuring effective oversight of ELV management.

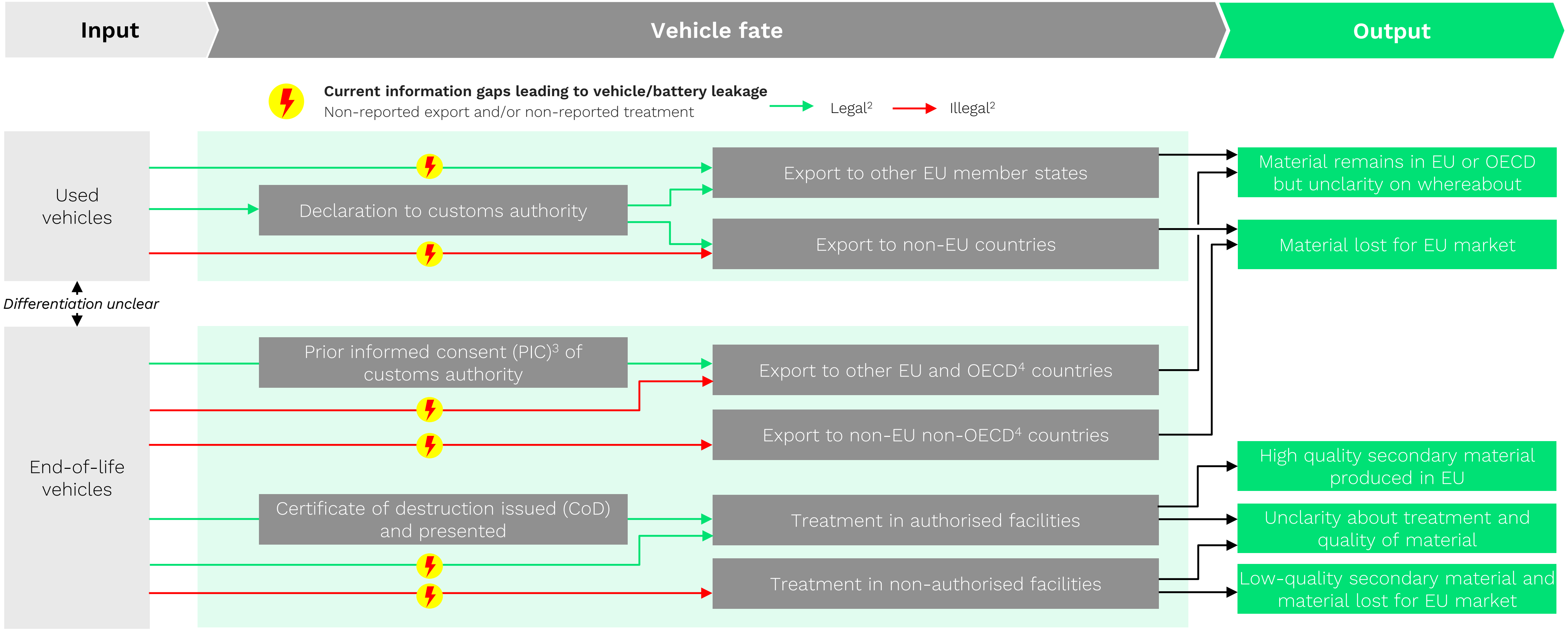
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

1) Qualitative assessment

1 Existing information gaps for EVs currently lead to unclarity on whereabout and treatment of the vehicle/battery, material leakage and low-quality recycling

BATTERIES WITHIN VEHICLES[1]

Overview on the vehicle fate and current information gaps



1. Batteries can also be treated or exported independently from the vehicle; yet leakage of battery within the vehicle currently considered to be most relevant.
2. European Commission (2021)
3. To be obtained when exporting hazardous waste according to UN law
4. The Waste Shipment Regulation bans export of hazardous waste outside of the OECD

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

❷ Integration of the battery passport into existing processes as well as additional data attributes could avoid illegal exports, illegal treatment and further non-reporting

Specifications beyond regulatory requirements...

Improvement potentials		Additional data attributes	+ Integration of battery passport in process
Quantified	(1) **Avoid illegal exports**	• *Amend "battery status" by* "exported" • "Name of authenticated exporter" • "Date of export" • "Destination"	Integration into **de-registration of used vehicles** and **export** control could support authorities in preventing illegal export: • De-registration of used vehicles: SOH accessible via the battery passport could support the differentiation between used vehicles and end-of-life vehicles (ELV) in the de-registration, only "used vehicles" eligible for export[2] • Export control: Additional data attributes on the passport could be used for verification of export by the customs authority and facilitate automated export controls (ESPR[1] (Art. 13) proposes an interconnection of the DPP registry with the EU Customs Single Window Certificates Exchange enabling automated exchange)
Quantified	(2) **Avoid illegal treatment**	• *Amend "battery status" by "recycled"* • "Name of authorised recycling facility" • "Date of recycling treatment" • "Battery owner"	Integration into **de-registration of ELVs** could support authorities in preventing illegal treatment: • De-registration of ELVs: Additional data attributes on the battery passport could be used to verify authorised treatment when de-registering a vehicle by linking it to the CoD that needs to be presented as a prerequisite to de-register an ELV – When the battery was recycled, additional data attributes could be used to validate treatment in an authorised recycling facility – If the battery was not recycled but sold as a spare part or for a second-life, the required battery's status options (repurposed, re-used, or remanufactured) could be used for verification
	(3) **Avoid non-reported exports** to other EU member states **and non-reported treatment** in authorised facilities (currently not illegal)	• *Same as (1) and (2)*	Integration into **market surveillance** could close further information gaps on whereabouts and fates of batteries, improving market oversight and potentially aiding efforts to increase collection: • The unique identifiers of the respective batteries as available on the passport could be linked to the quantities reported to the competent authorities[3] to identify disparities between batteries introduced to the market and those collected as waste

For all: Connection to circularity vehicle passport once implemented as well as integration of battery passport into future reviews of waste legislation

1. Council of the European Union (2023)
2. Could require exception for vehicles with battery swapping technology
3. Producer and waste management operators report to the component authorities, member states report to the Commission (see Battery Pass consortium (2023, p.42))

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

3 The process improvements result in economic, social and environmental impacts, e.g. increased supply security, recycling revenue and safety as well as reduced emissions

Overview on process improvements and resulting impacts

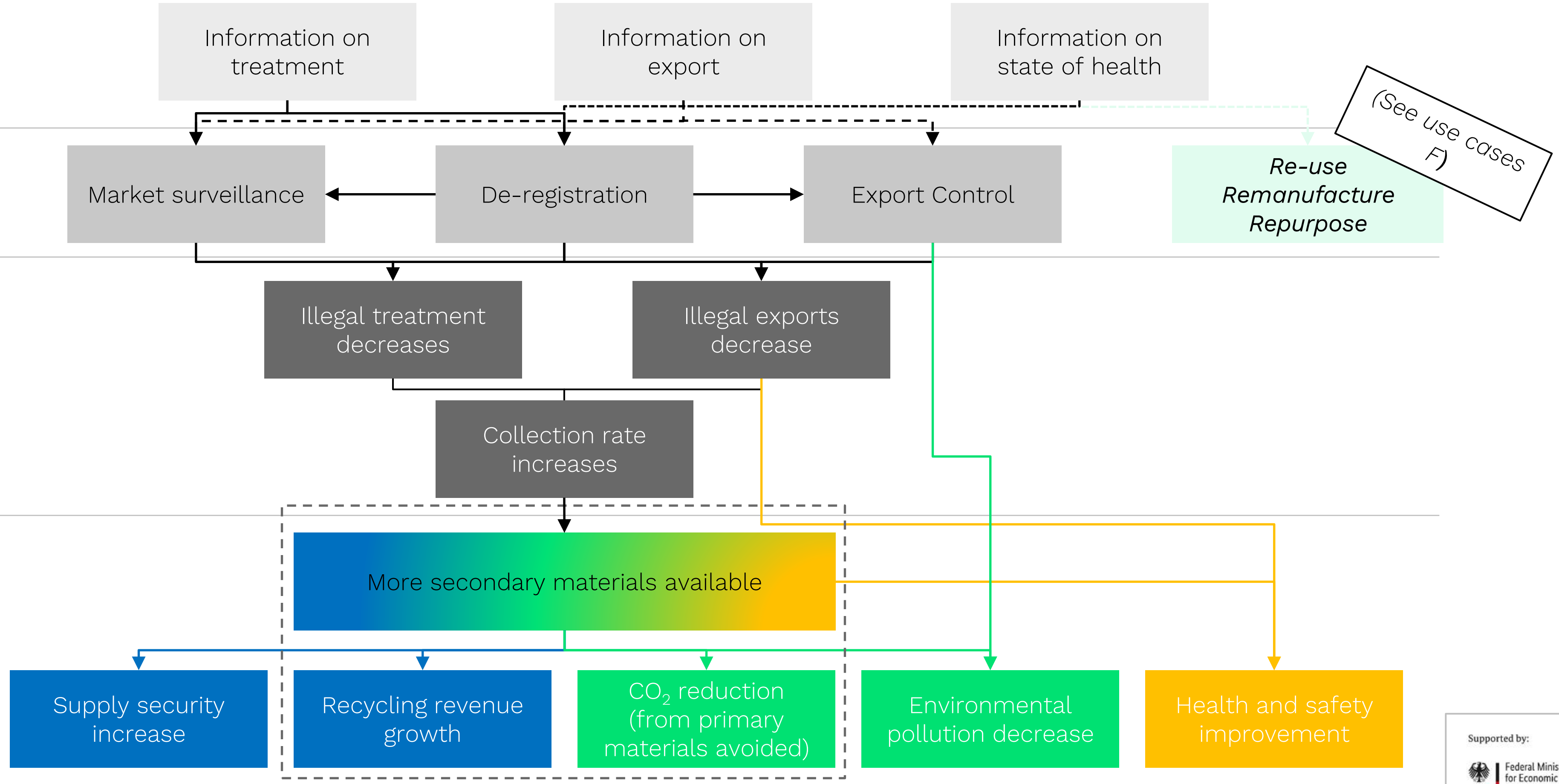
Economic impact | Social impact | Environmental impact | Quantified

Data availability
from battery passport

Integration
of the battery passport into existing processes

Process improvements
through data availability and integration

Impact dimensions
from process improvements



Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The quantification models potential impacts from increasing the end-of-life collection of EV batteries when reducing illegal exports and illegal treatment

Quantification modelling approach

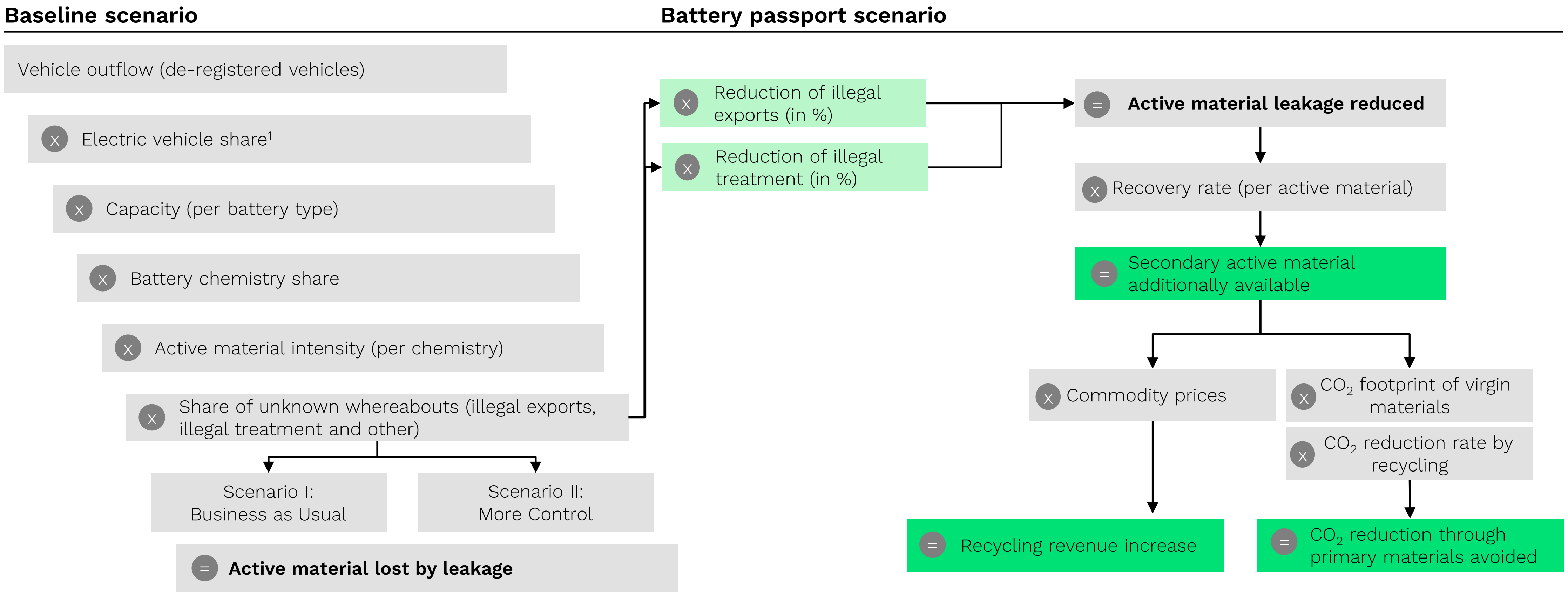
Scope	• Battery application: Electric passenger vehicles (BEV and PHEV) • Geography: Europe (EU27, Norway, Iceland, Switzerland and United Kingdom) • Timeframe: 2037-2045 (with the battery passport being required from Feb 2027, the respective batteries will reach their EOL earliest in 2037 with an average lifetime of 10 years assumed)
Level of analysis	**System-level perspective** (macroeconomic): EV battery collection in Europe • Secondary (active) materials additionally available in Europe [t] • CO2 reduced by additionally available secondary materials (primary materials avoided) [t CO2 eq.] • Revenue created by selling additionally available materials [EUR]
Scenarios	• **Baseline scenarios** (materials lost by leakage): – Business as usual: Average rate of vehicles with unknown whereabouts in Europe – More control: Best case in Europe achieved by efficient regional policy incentives1 (example of Denmark) • **Battery passport scenario** (based on below improvement potentials)
Improvement potentials	**Improvements with directly measurable impacts on baseline secondary material availability** in percentage ranges **Modelled** √ Reduction of illegal exports √ Reduction of illegal treatment **Not modelled, but additional benefits prevalent** × Accuracy of assessment increased × Reduction of non-reported exports to other EU member states and non-reported treatment in authorised facilities (currently not illegal)

1. Public awareness campaign and scrapping premium of EUR 300 per car, when presenting a certificate of destruction (see ADEME (2019))

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Under the battery passport scenario, secondary material is additionally available, which leads to increased recycling revenue and CO_2 reduction through avoiding primary materials

SIMPLIFIED — Input — Improvement potentials — Outputs



1. Sales share adoption rate displaced by 10 years (assumed lifetime)

See technical annex on slides 138-140 for main assumptions and their sources

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The battery passport could have the potential to reduce illegal exports and illegal treatment under certain conditions

Lever description	Assumptions	Required conditions
Reduction of illegal export • Around 40% of vehicles with unknown whereabouts are exported illegally.[1] • Integrating the battery passport in the de-registration of used vehicles and export control processes could reduce illegal vehicle exports. • (For more information, please refer to (1) on slide 94)	↓ 50-80%[2] decrease of illegal exports	• Interconnection of battery passport registry with national vehicle registration offices • Interconnection of battery passport registry with EU Customs Single Window Certificates Exchange • Additional data attribute on the battery passport • Definition of a minimum SOH value for an EV to be defined as roadworthy and therefore qualify for export as a used vehicle
Reduction of illegal treatment • Around 50% of vehicles with unknown whereabouts are treated in non-authorised facilities.[1] • Integrating the battery passport into the de-registration of ELVs could reduce illegal treatment of EVs and their batteries in non-authorised facilities. • (For more information, please refer to (2) on slide 94)	↓ 50-80%[2] decrease of illegal treatment	• Interconnection of battery passport registry with national vehicle registration offices • Additional data attributes on the battery passport • Battery passport included or linked to CoD of vehicle

1. European Commission; Oeko-Institut (2017)
2. Maximum reduction assumed to be 80%, as complete elimination of illegal exports or treatment is unlikely, yet further regulation pressure will promote a significant decrease. Minimum reduction set at 50%, as example of Denmark compared to the EU has shown that policy measures could reduce the proportion of unknown whereabouts, and thus illegal exports and treatment, by around 50%.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

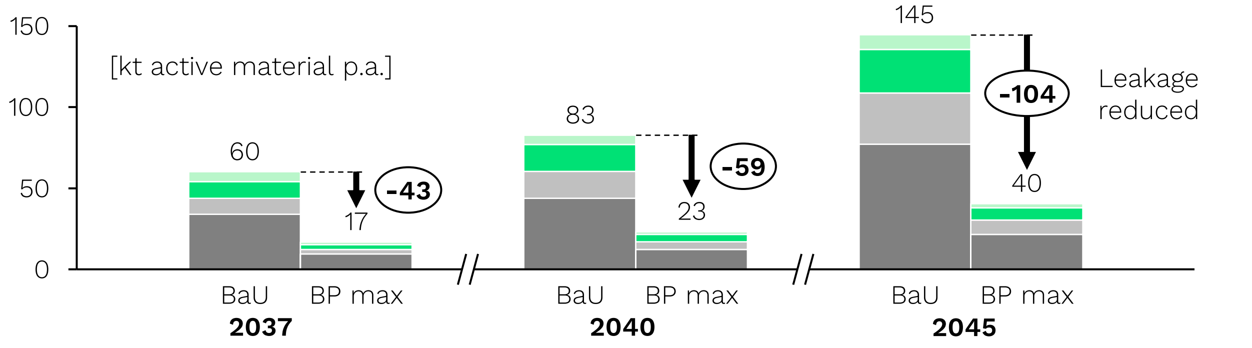
The reduction of battery leakage through the battery passport could lead to more secondary active materials available fulfilling ~ 5-20% of passenger EV demand in 2045

Cobalt Lithium Manganese Nickel

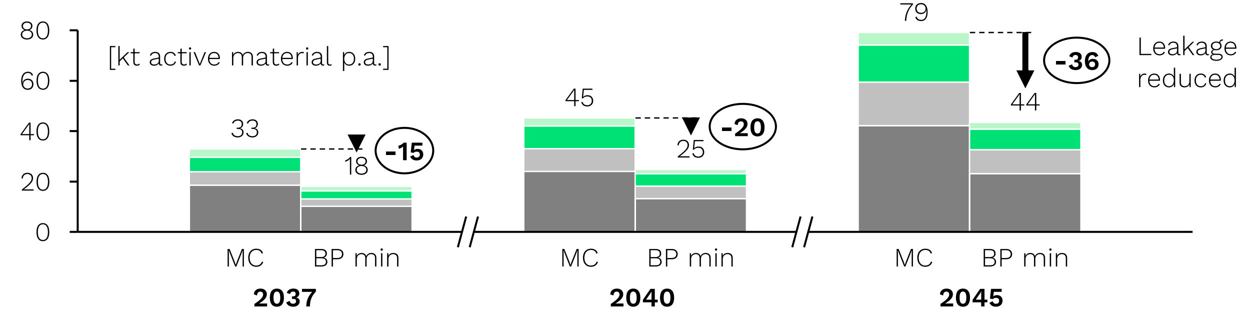
Macro perspective: Materials available on the European market

Leakage of batteries in baseline vs battery passport scenarios

Maximum expected reduction example:
Leakage of active material in business as usual (BaU) scenario vs. 80% reduction of illegal exports and treatment in battery passport scenario (BP max)



Minimum expected reduction example:
Leakage of active material in more control (MC) scenario vs 50% reduction of illegal exports and treatment in battery passport scenario (BP min)



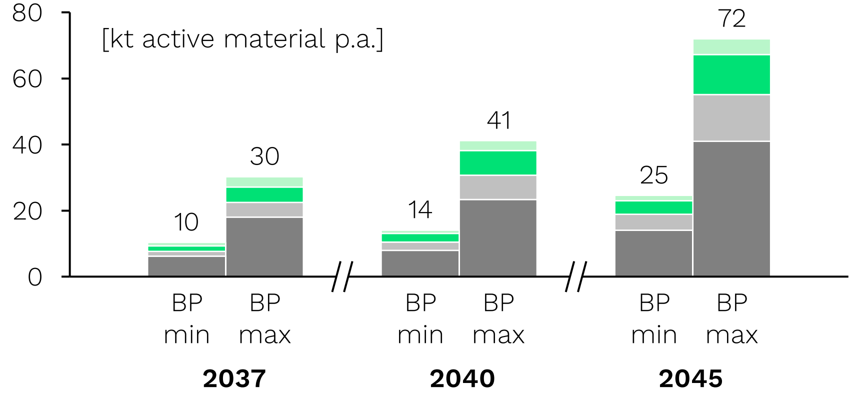
Secondary material additionally available

Interactive visualisation

By reducing the amount of battery leakage from the European market through battery passport levers, we estimate that by 2045:

- ~ 2-5 kt cobalt
- ~ 4-10 kt lithium
- ~ 5-15 kt manganese
- ~ 15-40 kt nickel

could be additionally available each year.



This could **fulfil between 5 and 20% of the active material demand** for passenger electric vehicles in Europe.

Source: Systemiq analysis (2024), based on various sources: vehicle outflow based on Heinrich Böll Stiftung (2023), electric vehicle share based on IEA (2023b), battery chemistry share based on Energy Transition Commission (2023), share of unknown whereabouts based on Umweltbundesamt (2020) etc., see technical annex on slides 136-138 for main assumptions and their sources

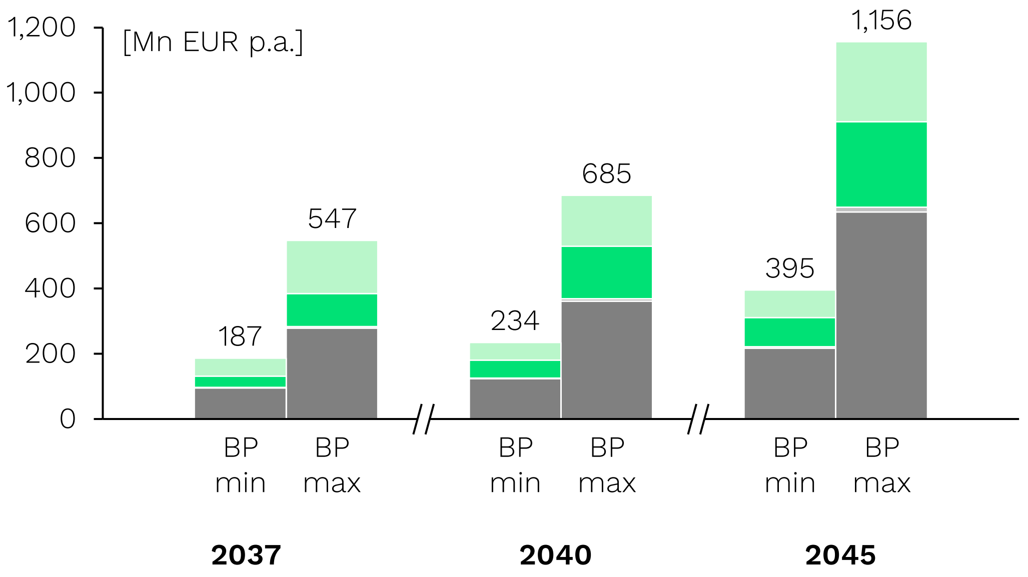
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Increased availability of secondary active material in the European market could increase recycling revenue by ~ 5-15% and reduce carbon emission by ~ 2-10%

Macro perspective: Recycling revenue increase and CO_2 reduction based on secondary materials additionally available on the European market

Recycling revenue increase

Due to the additional secondary active materials available from reducing battery leakage, we estimate that **European recyclers could increase their revenue by EUR ~ 400 – 1,200 Mn each year** starting 2045.

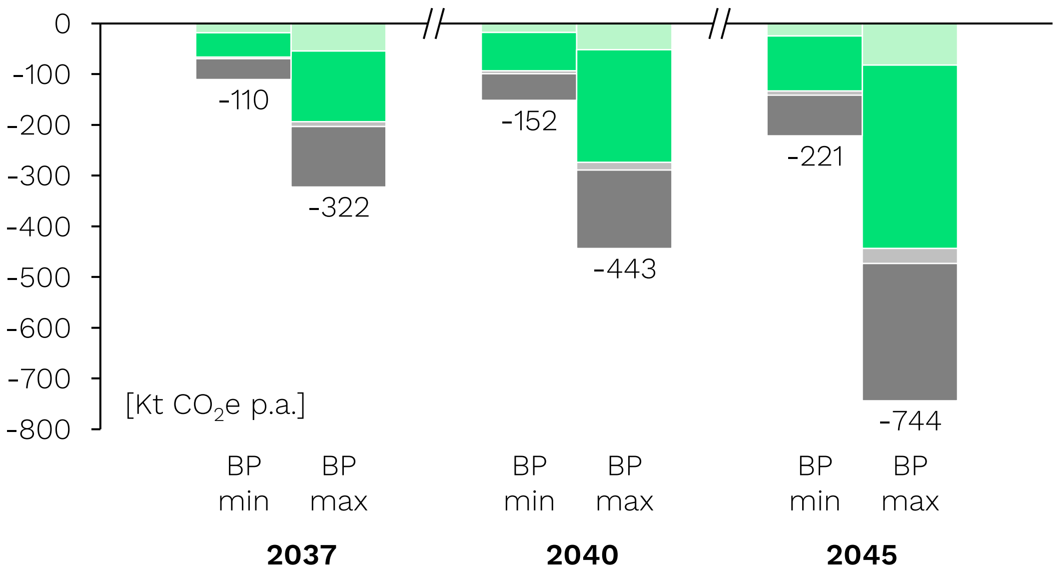


Source: Systemiq analysis (2024), commodity prices based on 5 year-averages from DERA (2023), see technical annex on slides 136-138 for main assumptions and their sources

Reducing battery leakage **could increase the revenue of the EU recycling market by ~ 5-15%.**[1]

CO_2 reduction through primary materials avoided

Due to the additional secondary active materials available from reducing battery leakage, we estimate that **~ 220-740 kt CO_2 equivalents could be reduced each year** starting 2045.



Source: Systemiq analysis (2024), emission factors based on Ecoinvent (2024), cut-off cumulative LCIA v.3.91.1, see technical annex on slides 136-138 for main assumptions and their sources

Reducing battery leakage could **reduce ~ 2-10% of the carbon footprint associated with the raw material extraction** of active materials required to meet the demand for EV batteries.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

1. Based on assumed EU market size of EUR 8 bn in recycling revenue without the battery passport (see Strategy& (2023))

Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
  - Enabled by application of traceability systems for data collection
  - Enabled by integration in regulated downstream processes
  - Enabled by aggregation of data from different passports
- Analysis on differences for industrial batteries

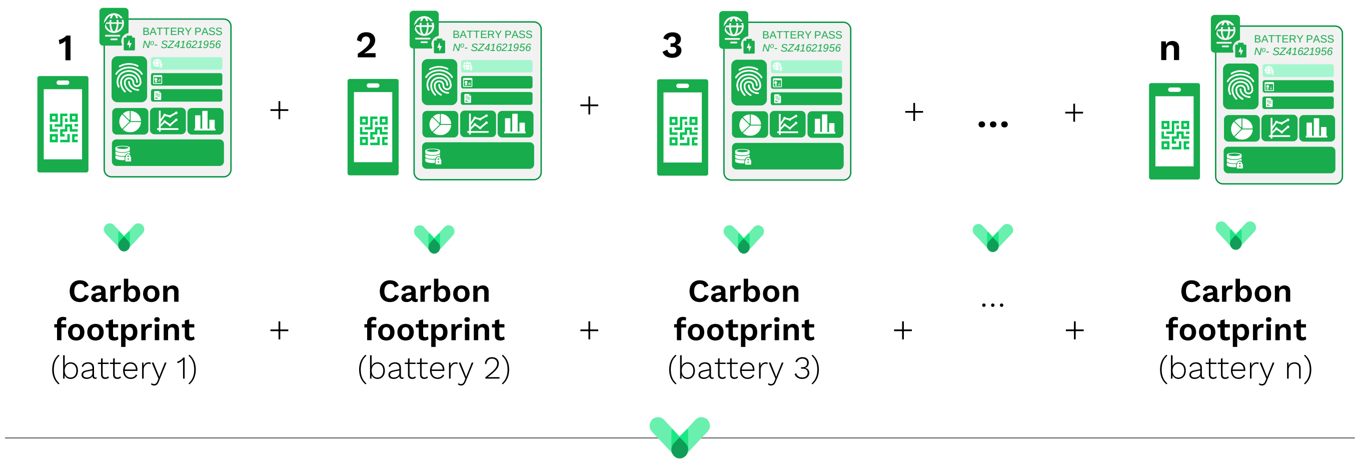
Battery passport data aggregation combines data of passports across an organisation or the market to provide additional information

The understanding of battery passport data aggregation

- Battery passport data aggregation is the **aggregation of** static or dynamic data **attributes over different battery passports**
- It is to be **differentiated from data aggregation in the battery upstream value chain,** where data is aggregated before being transferred to one battery passport
- The aggregated battery passport data could be categorised by different data attributes, e.g.
  - Battery category
  - Battery chemistry
  - Battery model
  - Manufacturing plant
  - …

The process of aggregating data from different passports[1]

Example: Battery carbon footprint



Different aggregation outputs[2]: e.g. average carbon footprint (battery 1, 2, 3, …, n)

1. More information on battery passport data aggregation and access through query mechanisms see slide 104
2. More information on possible aggregation outputs see slide 106

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Aggregation of data from different battery passports unlocks further use cases and could be done either on market or organisation level

Why is the aggregation of battery passport data important?

Several use cases with significant potential are **only possible with battery passport data aggregation**

- J – Industry benchmarking
- K – Accurate market overview
- L – Informed policy design

For other, direct use cases, **battery passport data aggregation** is no precondition, but **unlocks further benefits**

- B – Informed purchasing decisions
- G – Marketplaces for used batteries

Data aggregation level

Market level:

All potential use cases (J, K, L) require the aggregation of data sets over different battery passports **across the entire market**. Also, use case B and G are supported by battery passport data aggregation on market level.

Organisation level:

The direct use cases B and G are strengthened through the aggregation of data sets over different battery passports **across one organisation.**

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

The technical implementation of data aggregation could be solved through an EU Commission-provided infrastructure or managed by specialised service providers

How could battery passport data aggregation be technically implemented?[1] Two potential approaches

Aggregation infrastructure provided by EU Commission

Storage of specified battery passport data in an aggregation layer

EU COM provides and manages infrastructure of an IT system for aggregation, here called "aggregation layer".

- Economic operator provides (pre-aggregated) anonymous battery passport data for aggregation layer
- Architecture of aggregation layer must be interoperable with the DPP system and is to be defined in standardisation

Aggregation process managed by service providers

Collection of battery passport data for data aggregation

Service provider sets up and manages aggregation of battery passport data.

- Service provider collects and uses publicly available battery passport data *AND/OR*
- Service provider accesses data through legal agreement with economic operator(s)

Battery passport data aggregation and access through query mechanisms

- Data could be searched for through query mechanism (EU Commission)
- Data could be searched for through query mechanism (service providers)

Access of aggregated battery passport data

- Aggregated data could be accessed **via the Web Portal[2]** (EU Commission)
- Aggregated data could be accessed **through a platform** operated by the service provider

1. Battery passport data might be missing partially or completely (e.g. due to connectivity reasons) during (pre-) aggregation processing and calculations. This issue has to be considered and handled properly to prevent incorrect results.
2. More information on the Web Portal see slide 105

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

A web portal or independent platforms could allow for the access of aggregated data on market level and depend on the access right group

Sourcing of battery passport data for aggregation

Aggregation of data requires access to battery passport data, which could generally be accessed via

- Data carrier and unique identifier
- Web portal

The **web portal is more suitable as data source for aggregation** as it includes searchable information of different battery passports.

Data carrier and unique identifier only provide access to the information of one individual battery passport.

	Web Portal as described in Recital 34a and Article 12a of the ESPR[1]	**Independent Platforms** as defined through individual contracts between economic operators and service providers
Set-up and Management	By the Commission	By service providers (economic operators)
Information	Web portal should allow stakeholders to search for information (on market level) included in product passports	a) Publicly available information (on market level) OR b) Information defined by economic operator (on organisational level)
Access	Stakeholders could search for information depending on their respective access right group (as specified in delegated acts): • "General public" • "Notified bodies, market surveillance authorities and the Commission" • "Any natural or legal person with a legitimate interest"	a) Public access OR b) Access defined by economic operator

1. The Web Portal is not mentioned in the EU Battery Regulation, only in the ESPR. The Web Portal's functioning is not described in detail. Its set-up and management lay within the responsibility of the Commission.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

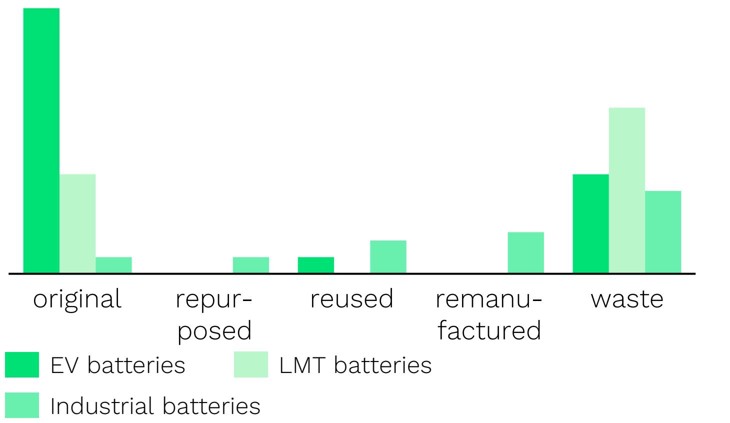
Different aggregation outputs such as average values or distributions are possible and could be regarded with respect to e.g. the battery category, calendar year or lifetime

Illustrative results of battery passport data aggregation

Depending on data attribute and its format, different aggregation outputs such as average values or distributions are possible. The aggregated information may be categorised per battery category (**Example 1**), the calendar year (**Example 2**) or battery age (**Example 3**), for example.

Example 1: Battery status[1]

Number of batteries in the different battery status options, per battery category[2]



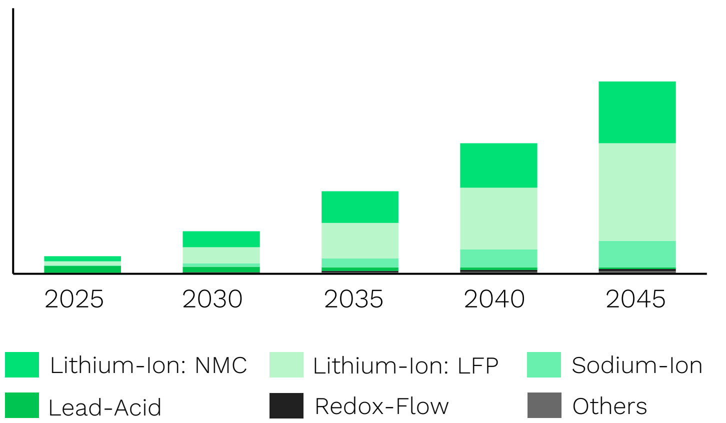
Format: String (text)

Access: Persons with a legitimate interest and Commission (OR as defined by economic operator[3])

Information level: Market (OR organisational[3])

Example 2: Battery chemistry in EU Market[1]

Battery mass [t] in EU market in different calendar years, per battery chemistry



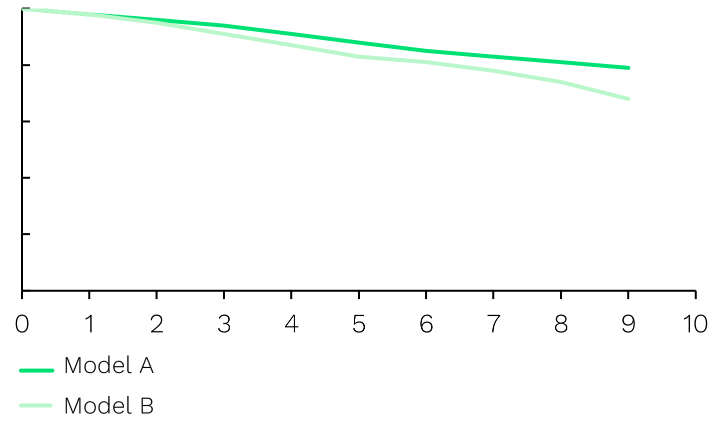
Format: String (text)

Access: Public

Information level: Market

Example 3: Remaining capacity[1]

SOCE [%] per battery age [years] for different battery models



Format: Decimal/integer

Access: Persons with a legitimate interest and Commission (OR as defined by economic operator[3])

Information level: Organisation

1. Arbitrary data
2. e.g. EV batteries will be repurposed as industrial batteries that will have a battery status "repurposed"
3. If the data aggregation process is managed by service provider and the data usage is determined by legal agreement between economic operator and service provider

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

J Industry benchmarking: Data aggregated from battery passports could be used for own benchmarking purposes or to guide consumer and investor decisions

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case · Potential use case · Not applicable

Battery passport user: Business · Authority · Private consumer

1 Situation without battery passport

Today, reference values to compare and evaluate the battery industry, specific players and their products along several dimensions such as technical as well as sustainability performance are limited, often relying on individual company statements rather than providing a comprehensive market level overview. Rapidly changing technological advancements, particularly in emerging battery chemistries and manufacturing processes further complicate maintaining an up-to-date comparison.

2 Improvements with battery passport

Based on data aggregated from battery passports, reference values could be determined, and benchmarking performed. Relevant aggregated battery passport data for this use case include:

- Carbon footprint (carbon footprint as declared and performance class)
- Supply chain due diligence (information indicated in the due diligence report)
- Circularity and resource efficiency (recycled content)
- Performance and durability (rated capacity, expected lifetime, etc.)

3 Benefits (along impact dimensions)

Economic (level of impact: High)

- Aggregated data on technical and sustainability performance of the industry could prompt organisations to enhance their performance for maintaining or increasing competitiveness
- By leveraging aggregated data for promoting better performing products through comparison, the respective market position could be improved, and sales and profits be increased
- Business models of benchmarking providers could draw on aggregated data

Environmental (level of impact: Middle)

- Visibility of environmental performance in comparison to the market could drive the entire value chain towards competing through less carbon-intense products and an overall more environmentally friendly market

Social (level of impact: Low)[1]

- Transparency on a battery model's social impact compared to the market could incentivise producers to implement practices and standards to decrease the social risks associated with the battery production

Applicability to industrial batteries[2]: ✓ Equally applicable for industrial batteries with BMS – Less applicable for industrial batteries without BMS

1. The battery passport connects to a Due Diligence report outlining social risks and mitigation measures by the economic operator. In contrast to the environmental indicators, this information is not easy to evaluate or compare, diminishing the effectiveness of this benefit.
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

K Accurate market overview: Aggregated information on batteries could improve market studies and projections, aiding business planning activities along the value chain

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case · Potential use case · Not applicable

Battery passport user: Business · Authority · Private consumer

1 Situation without battery passport

Businesses along the entire value chain require precise planning to align resources (human resources as well as assets like plants or machines) in accordance with certain material flows. However, battery demand and downstream flows are volatile and difficult to predict. In order to strategically plan their business activities, market studies and projections are conducted, yet obtaining accurate real-world data is difficult.

2 Improvements with battery passport

Information aggregated from battery passports could increase the accuracy of market studies and forecasts through real-world data and thus improve the market overview needed by companies in the entire value chain for their planning activities. In aggregated form, the following data attributes provide an insight into the material flows and battery capacity on the market:

- General information (manufacturing info, battery weight, battery status)
- Materials and composition (battery chemistry, critical raw materials)
- Circularity and resource efficiency (recycled content shares)
- Performance and durability (rated capacity, expected lifetime)

3 Benefits (along impact dimensions)

Economic

- Enhanced accuracy in predicting battery inflow empowers downstream businesses such as remanufacturers, collectors or recyclers to optimise their asset utilisation, thus increasing their revenue
- Real-world data on battery material flows and capacity could improve demand forecasts and thereby support upstream players such as CAM or cell manufacturers in mitigating the financial risks of the dynamic battery market and ensuring competitiveness

Environmental

- Through an improved overview on material flows, second-life strategies are encouraged as they could become economically more profitable, which would result in extending the battery's lifetime and therefore reducing its environmental footprint

Social

- N/A

Applicability to industrial batteries[1]: ✓ Equally applicable for industrial batteries with BMS · – Less applicable for industrial batteries without BMS

1. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

L Informed policy design: More accurate data on the battery stock aggregated from battery passports could support fact-based policy design

Level of impact: No / Low / Middle / High

Value chain in scope

Battery passport creation

Mining | Refining | Precursor and CAM production | Cells and modules manufacturing | Pack assembly and integration | Usage | Re-use Remanufacture Repurpose | Collection | Recycling

Direct use case | Potential use case | Not applicable

Battery passport user: Business | **Authority** | Private consumer

1 Situation without battery passport

So far, regulatory institutions are missing a comprehensive overview on battery market dynamics. The EU Battery Regulation partly addresses this shortfall via its public reporting requirements, though no information in aggregated format with a link to the actual batteries currently exists. To make effective decisions and interventions in the rapidly evolving battery industry, policymakers require a consolidated and up-to-date dataset.

2 Improvements with battery passport

Access to aggregated data derived from battery passports could enable informed policy design. The data could provide a comprehensive overview of battery market dynamics and associated environmental and social risks. This spans various sustainability dimensions, mainly but not limited to:

- General information (manufacturing info, battery status)
- Carbon footprint (carbon footprint as declared and performance class)
- Supply chain due diligence (information indicated in the due diligence report)
- Materials and composition (battery chemistry, critical raw materials)
- Circularity and resource efficiency (recycled content)
- Performance and durability (rated capacity, expected lifetime etc.)

3 Benefits (along impact dimensions)

Aggregated battery passport data on:

Economic (impact: Middle)

- General information as well as material and composition would allow tracking material flows and trends, informing policies targeted at reducing dependencies on specific resources or regions and increasing supply chain resilience
- Performance and durability could support policymakers with information on available batteries for repurposing or recycling, facilitating the implementation of policies (e.g. incentive schemes) to bolster industry capacities in handling the anticipated battery volume

Environmental (impact: High)

- The carbon footprint by battery category and chemistry would enable policymakers to better specify carbon footprint thresholds and incentivise better performing battery technologies
- Battery chemistries and actual recycled content shares could enable policymakers to compare these with target values for relevant materials in place, balancing environmental objectives with market feasibility
- Performance and durability allow an assessment for setting adequate minimum requirements for batteries, increasing their lifetime and reducing the total resources used for batteries

Social (impact: Low[1])

- The due diligence report would allow policymakers to get a clearer view on social impacts and risks, thereby improving the basis for revising social requirements such as the recognition of specific supply chain due diligence schemes

Applicability to industrial batteries[2]: ✓ Equally applicable for all industrial batteries

1. The battery passport connects to a Due Diligence report outlining social risks and mitigation measures by the economic operator. In contrast to the environmental indicators, this information is not easy to evaluate or compare, diminishing the effectiveness of this benefit.
2. For more information, please refer to subchapter on slides 110-119

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 4: Benefits

- Overview
- Direct use cases
- Potential use cases
- Analysis on differences for industrial batteries

The applicability of the use cases to industrial batteries must consider the varying requirements and characteristics of industrial battery subgroups

Industrial batteries definition

Industrial batteries defined by EU Battery Regulation as any battery:

- Specifically designed for industrial use;
- Intended for industrial use after being prepared for re-use;
- Or any other battery that weighs more than 5 kg and is neither EV, LMT, portable, or SLI battery.

Many cell chemistries, battery system designs and applications fall under this definition

Motivation

Industrial batteries subgroups have **specific requirements and characteristics**, leading to **varying applicability of** the general **use case assessment.**

Example – Lead-acid batteries:
Lack of battery management system and connectivity: Inability to record and evaluate the battery's characteristic dynamic data has direct impact on applicability of Battery Pass use cases.

Scope of the extended analysis

- Identification of **key differences** for industrial batteries compared to general use case scope;
- Analysis of **impact of differences** on the benefits defined for the individual use cases;
- Overall assessment of **use case applicability for industrial batteries** (and their subgroups).

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Main characteristics for industrial batteries regarding approach to use case analysis

Diverse industrial battery market

- Broad range of applications and (re) manufacturers
- Home storage only major B2C application
- Forklifts dominate traction market

Broad variation of battery chemistries, two clusters

- **BMS/no BMS:** Dynamic data not available without BMS and connectivity
- Varying processes for different chemistries

Legal requirements are heterogeneous

Specifications in the EU Battery Regulation for different industrial battery subgroups

Identify
within use cases scope

- **Differing market conditions and processes** for industrial battery applications

- **Lacking dynamic data** without BMS
- **Varying processes** without BMS/regarding different chemistries

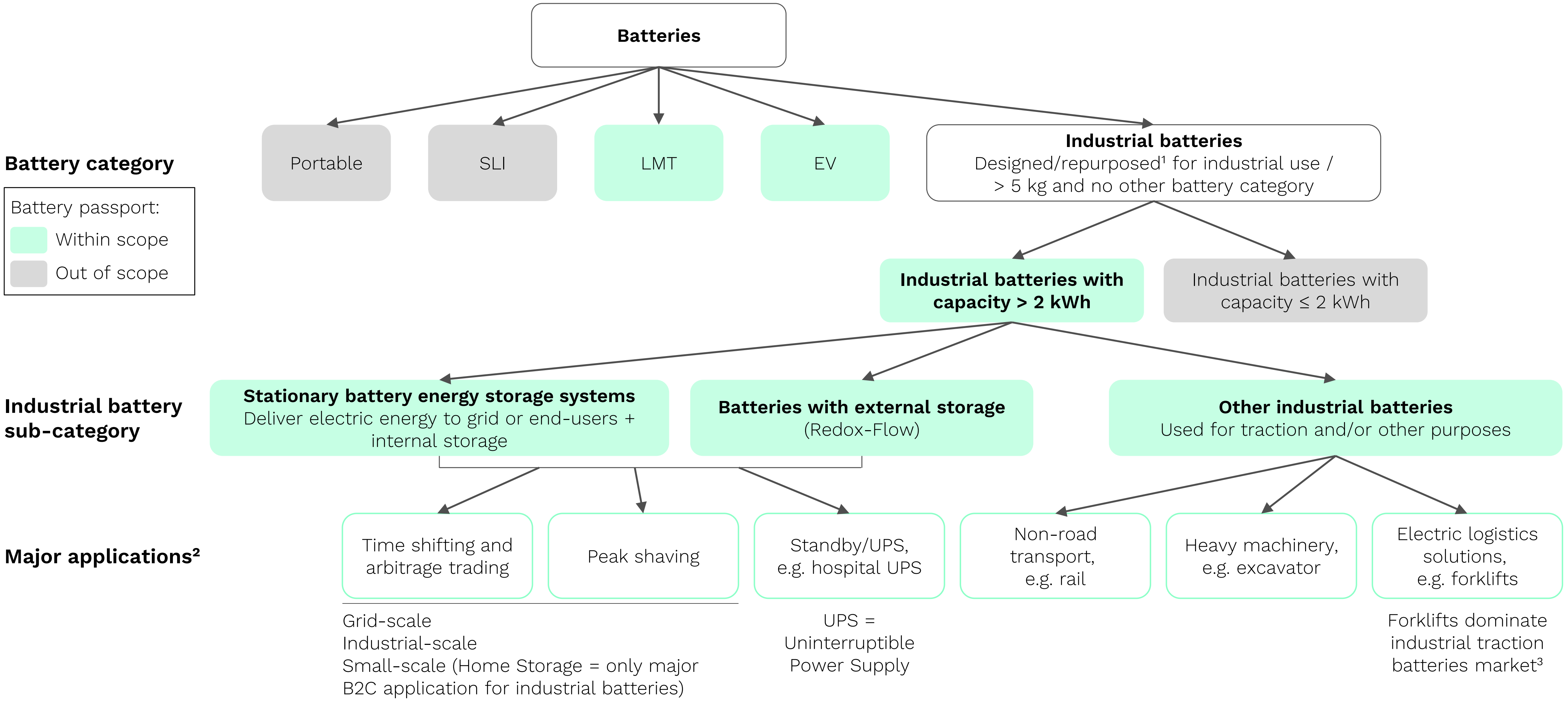
- **Differing data requirements** for subgroups

Analyse
Impact of differences on benefits defined for the individual use cases

Assess
Applicability of general use case assessment to industrial batteries

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Industrial batteries are characterised in different sub-categories and a broad range of applications, with varying market conditions and processes affecting the use cases



1. A number of industrial batteries may be repurposed batteries (e.g. a former EV battery is repurposed into an industrial battery). However, repurposing used industrial batteries is a less likely scenario.
2. Market conditions and processes (e.g. servicing processes) can vary among industrial batteries applications, resulting in an impact on the applicability of the overall use case assessment.
3. cf. Global Market Insights Report (2023)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

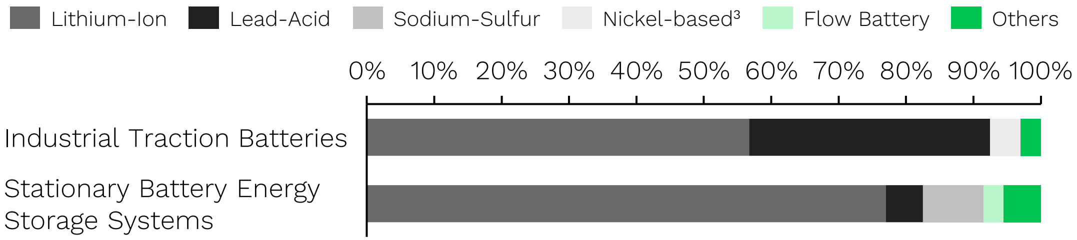
Industrial batteries encompasses a broad range of battery chemistries and technologies with specific characteristics that affect the use case assessment

Exemplary overview of diverse chemistries and technologies used in industrial batteries:

	Chemistry / Technology	Application: Industrial Traction	Application: Stationary Storage
BMS	Lithium-Ion	X	X
	High Temperature	X	X
	Redox-Flow		X
	Lithium-Sulfur	X	X
	Sodium-Ion	X	X
No BMS	Lead-Acid	X	X
	Nickel-Based	X	X

Emerging chemistries (grey shading: Lithium-Sulfur, Sodium-Ion)

Global market share by battery chemistry (2022)[2]



Dynamic data in the battery passport is **not available without BMS and internet connectivity.** This requires distinction of batteries with and without BMS/connectivity[1].

Chemistries involve **varying characteristics and processes,** e.g. different safety aspects and recycling processes for Li-Ion and Pb-Acid.

These specific characteristics **affect the applicability of the general use case assessment to industrial batteries**

1. It is currently assumed that all batteries should have a BMS and log dynamic data. Discussions ongoing on how to handle batteries currently without BMS, e.g. monitoring-only tools for lead-acid batteries.
2. Estimation, Global Market Insights (2023)
3. In the diagram, high temperature zebra (Sodium Nickel Chloride) batteries are classified as Nickel-based.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Excursus: Batteries with external storage differ greatly from the other battery systems, even in industrial batteries

Characteristics of batteries with external storage

Definition per Battery Regulation:
"...a battery that is specifically designed to have its **energy stored exclusively** in one or more **attached external devices**."[2] This type of battery relates primarily to **Redox-Flow** systems.

Technology

Most commonly **energy** is stored in the liquid **electrolyte** that circulates in two separately pumped circuits.

The electrolyte reacts in the cell's **membrane stack, releasing electrical energy**.

Most common **electrolyte chemistry: Vanadium-redox** or **zinc-bromine**.

System design

Usually large systems with **high capacities.**

Capacity correlates with the **stored** amount of **electrolyte** and **contained concentration of charge carriers** inside of the storage containers.

Power can be scaled **independently from capacity** through design of the stack.

Data availability

Due to system design, the **BMS can extract less information** than for lithium-ion batteries: Some data points can only be accurately determined by chemical sampling.

Dynamic data is **less relevant for safe operation** of such a system.

Use phase / End-of-life

The **valuable material** is the **electrolyte**[1] and the systems have **long lifetimes.**

E.g. the **electrolyte** in vanadium-based **batteries degrades little** during use and can be treated to restore capacity.

At EoL, some **electrolytes can be removed** and **re-used** or **recycled.**

Effects on the battery passport

- **Several battery passport data not applicable**, in particular performance and durability data:
  - **Dynamic monitoring of resistance or capacity fade** are **less meaningful** for such systems
- **Vastly different evaluation methods** for data attributes, including definition of **system boundaries, e.g.**
  - **Performance and durability data,** e.g. remaining capacity
  - **Carbon footprint**
- **Dynamic data more scarcely available**

The differences for batteries with external storage are included in the analysis on this general level. An assessment of any deviating detail, however, is out of scope for this work.

1. Majority of remaining system components, such as piping or membranes, are usually made of polymer and less valuable
2. Art. 3, 1(8)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

§ The EU Battery Regulation specifies several diverging rules for the different industrial battery sub-categories that affect the use case assessment

Article 8	**Recycled content** in industrial batteries, electric vehicle batteries, LMT batteries and SLI batteries
Article 10	**Performance and durability requirements** for rechargeable industrial batteries, LMT batteries and electric vehicle batteries

Within the category "industrial batteries", the **rules** in **Articles 8** and the **minimum values** laid out in **Article 10 apply only to industrial batteries with a capacity greater than 2 kWh, except those with external storage.**

Article 12	**Safety** of stationary battery energy storage systems
Article 14	Information on the **state of health** and **expected lifetime** of batteries

The **rules** in Article 12 **apply only to stationary battery energy storage systems** (SBESS) and in **Article 14 only to SBESS** within the category "industrial batteries".

Article 7	**Carbon footprint** of electric vehicle batteries, rechargeable industrial batteries and LMT batteries

The **rules** in Article 7 shall **apply** 54 months **later for rechargeable industrial batteries with external storage** compared to all other rechargeable industrial batteries, corresponding delegated/implementing acts 48 months later.

The various industrial battery subgroups have **different requirements as to which data attributes must be reported for the battery passport** and from which point in time.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

A separate analysis for industrial batteries shows the applicability of all use cases while highlighting differences due to technological, usage, and business characteristics (1/3)

General use case	Applicability[1]	Key takeaway for industrial batteries specific analysis[2]
(A) **Reliable communication of ESG data**	✓ All industial batteries	For industrial batteries, the **overall benefits regarding reliable communication of ESG data remain consistent.** In the case of **batteries with external storage**, the **key aspects** of the general use case scenario could be **leveraged at a later time or on a voluntary basis.**
(B) **Informed purchasing decisions**	✓ Industrial batteries with BMS – Industrial batteries without BMS	The **battery passport supports informed purchasing decisions for industrial batteries with BMS/connectivity**, offering analogous benefits to the general use case. **The applicability is reduced for industrial batteries without BMS/connectivity** as they lack detailed dynamic data that can inform purchasing decisions **after a usage period**.
(C) **Eased servicing**	– All industrial batteries	**Battery passport data could facilitate inhouse servicing and predictive maintenance** for industrial batteries. **Yet, benefits for servicing through independent workshops is less applicable** because of predefined service contracts or processes that are predominant for most industrial batteries. Moreover, **benefits arising from dynamic data do not apply to industrial batteries without BMS/connectivity.**
(D) **Precise risk assessment for transport of used/ waste batteries**	✓ Industrial batteries with BMS – Industrial batteries without BMS X Industrial batteries with external storage	The risk assessment for transportation of used/waste batteries with BMS benefits from dynamic data via the battery passport independent of battery category and the **use case** is therefore **equally applicable to industrial batteries with BMS**. The **risk assessment of industrial batteries without a BMS** (e.g. Pb-acid, Ni-based) is less complex and **does not require dynamic data** via the battery passport. **Transportation restrictions differ for batteries with external storage** and **benefits** from battery passport data **do not apply.**

1. General use case applicability to industrial batteries: ✓ Equally applicable – Less applicable X Not applicable

2. Please refer to the annex (slides 141-153) for a detailed use case by use case analysis on differences for industrial batteries

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

A separate analysis for industrial batteries shows the applicability of all use cases while highlighting differences due to technological, usage, and business characteristics (2/3)

General use case	Applicability[1]	Key takeaway for industrial batteries specific analysis[2]
(E) **More efficient recycling processes**	✓ Industrial batteries with Li-Ion and emerging chemistries – Industrial batteries except Li-Ion and emerging chemistries	The use case for **more efficient recycling processes is applicable to batteries with Li-ion or emerging chemistries independent of battery category.** Handling of **other battery chemistries** such as Pb-acid, NiMH or those in batteries with external storage, however, **do not need advanced sampling or complex dismantling**, so that the data contained in the battery passport offers **less added value.**
(F) **Simplified residual value determination**	– All industrial batteries	Due to more exhaustive service lives of **industrial batteries**, they are **rarely used in second life applications.** Therefore, the **residual value determination** is **only needed for transfer of ownership within the same application, which limits the applicability of the use case.** Exceptions could be heavy duty applications, e.g. in agriculture & construction. Additionally, the **absence of dynamic data for industrial batteries without a BMS/connectivity limits the potential of the use case** further for this subgroup.
(G) **Streamlined trade of used/waste batteries through marketplaces**	✓ All industrial batteries	The **battery passport could be leveraged for streamlined trade of used/waste batteries through marketplaces equally for industrial batteries**. The different handling of batteries downstream, where these batteries are typically directly recycled rather than re-used or re-purposed does not affect the benefits of their streamlined trade.
(H) **Efficient data exchange and reporting based on upstream traceability**	✓ All industrial batteries	**Battery passport data requirements** that could be **fulfilled through a traceability system enable a more transparent supply chain equally for all industrial batteries**, with negligible differences compared to the general analysis of this use case.

1. General use case applicability to industrial batteries: ✓ Equally applicable – Less applicable X Not applicable

2. Please refer to the annex (slides 141-153) for a detailed use case by use case analysis on differences for industrial batteries

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

A separate analysis for industrial batteries shows the applicability of all use cases while highlighting differences due to technological, usage, and business characteristics (3/3)

General use case	Applicability[1]	Key takeaway for industrial batteries specific analysis[2]
(I) **Increased end-of-life collection**	– All industrial batteries	For industrial batteries, **predetermined and monitored take-back processes** already result in a **higher collection rate** compared to EV batteries. Additionally, the **bulkiness and immobility** of many industrial batteries serve as **barriers to illegal exports**. Consequently, the **potential use case of increased end-of-life collection**, facilitated by additional non-mandatory information on the battery passport, is **less applicable to industrial batteries**.
(J) **Industry benchmarking**	✓ Industrial batteries with BMS – Industrial batteries without BMS	**Aggregated data could enable benchmarking** of industrial batteries **with benefits** of the general use case **remaining consistent for industrial batteries with BMS.** However, **no benchmarking of detailed dynamic performance data** is possible for batteries **without BMS/connectivity**.
(K) **Accurate market overview**	✓ Industrial batteries with BMS – Industrial batteries without BMS	**Aggregating data** of battery passports **could enable an accurate market overview** equally **for industrial batteries with BMS,** with negligible variations in data availability. However, a **detailed market overview specifically relating to batteries' conditions** (e.g. state of health) is **not available for industrial batteries without BMS/connectivity.**
(L) **Informed policy design**	✓ All industrial batteries	Almost all battery pass data attributes could contribute to this use case. **Overall**, the **data availability** deviates **little for industrial batteries** with negligible impact on the use case benefits. Therefore, **informed policy design enabled through aggregating passport data applies equally to all industrial batteries.** Given the broader variance in industrial applications, **additional differentiation in application-specific information would add further benefits to this use case.**

1. General use case applicability to industrial batteries: ✓ Equally applicable – Less applicable X Not applicable

2. Please refer to the annex (slides 141-153) for a detailed use case by use case analysis on differences for industrial batteries

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Chapter 5: Challenges and drawbacks

Stakeholders might need to overcome certain challenges when creating, maintaining or using the battery passport

Challenges

- Difficulties or obstacles that **stakeholders are facing when creating, maintaining or using the battery passport**
- **Unmitigated challenges could lead to unnecessary drawbacks** reducing the net value of the battery passport

1 Technical and battery passport system challenges

← *Reinforcing* →

2 Capabilities and resources challenges

1 Technical and battery passport system challenges

- Connected to required technical design of the battery passport
- Relevance varies based on stakeholder's role in the system
  - Action needed for mitigation: Industry collaboration, investments in emerging technologies and authority support in enforcing standards, etc.

2 Capabilities and resources challenges

- Linked to the individual abilities of stakeholders
- Relevance varies based on stakeholder's size[1] and capabilities
  - Action needed for mitigation: Early intra-organisational alignment, harmonisation and support for most affected businesses, etc.

1. Only applicable for businesses

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

1 Technical and battery passport system challenges: Industry collaboration, investment in emerging technology and authorities enforcing standards needed to overcome challenges

NOT EXHAUSTIVE[1]

Technical and battery passport system challenges

Technical set-up	• Unavailability of harmonised standards • Lack of reliable, interoperable infrastructure • Inefficiencies in handling large data volumes • Complexity of integrating data into existing systems • Limited access to crucial IT resources
Data security	• Lack of robust security measures • Risk of intellectual property rights infringement • Exposure to unauthorised access risks • Concerns about privacy and security of personal data
Data accuracy	• Lack of audit processes • Insufficient data quality, lacking reliability • Data inconsistencies and contradictions
Colla-boration	• Missing of data-sharing agreements • Limited trust among stakeholders • Difficult coordination within and between organisations

Action needed for mitigation

Policymaker and authorities:

- Define clear, consistent and specific regulatory requirements
- Consult and consider feedback from industry representatives
- Facilitate the development and adherence to harmonised industry standards
- Establish and enforce stringent regulations to ensure data security
- Provide support for research and developments addressing technical challenges

Businesses:

- Prepare early and implement simple “fallback plans” due to complexity of new subjects and technologies
- Participate in standardisation efforts
- Invest in emerging technologies to build an interoperable infrastructure and facilitate data exchange
- Implement robust data governance frameworks to ensure data security

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

2 Capabilities and resources challenges: Early intra-organisational alignment, harmonised requirements and financial support needed to overcome challenges

NOT EXHAUSTIVE[1]

Capability and resource challenges

Financial constraints	• Limited financial resources • Financial risks, including for third-party services and security breaches • Increased costs for personnel and IT
Inexpe-rience	• Knowledge gaps and technical complexities • Human resource scarcity and skill shortage • Difficulties in understanding and interpreting complex technical data • Lack of skills to navigate and understand digital platforms
Internal complexity	• Complex coordination across departments and teams • Organisational resistance • Limited understanding of purpose and benefits
Regulatory complexity	• Numerous and stringent regulatory requirements • Uncertainties in European regulatory framework • Diverse requirements across various countries or regions

Action needed for mitigation

Policymaker and authorities:
- Define clear, consistent and specific regulatory requirements
- Provide financial support or incentives to businesses most affected by challenges
- Harmonise requirements with other national and international regulations
- Raise awareness and inform businesses, consumers and other stakeholders about the requirements

Businesses:
- Align early within the company to streamline coordination and overcome resistance
- Invest in training and hire experienced workforce
- Explore industry networks and collaboration on data exchange (such as Catena-X and GBA)
- Form strategic partnerships with technology providers
- Discuss requirements with customers and supply chain partners and adjust contracts

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Technical and battery passport system challenges mostly affect the passport issuer; capability and resource challenges mainly impact SMEs

Relevance of challenges by stakeholder

Low · Medium · High · Business · Authority · Private consumer

1 Technical and battery passport system

Role in the system	Data provider (e.g. miner) [Business]	Data receiver and provider (e.g. cell manufacturer) [Business]	Passport issuer (e.g. automotive OEM)[1] [Business]	Data receiver (e.g. recycler, end-consumer, authorities) [Business, Authority, Private consumer]
Technical set-up	Medium	Medium	High	Medium
Data security	High	High	High	Low
Data accuracy[2]	Medium	Medium	High	High
Collaboration	Low	Medium	High	Low

Impact expected to be **highest for the role of the passport issuer** (economic operator responsible for the battery passport)

2 Capabilities and resources

Size and capabilities	SME[3] [Business]	MNC[4] [Business]	Authorities [Authority]	End-consumer [Private consumer]
Financial constraints	High	Low	Medium	Low
Technological inexperience	High	Medium	High	Low
Internal complexity	Medium	High	Medium	Low
Regulatory compliance	High	High	n/a	Low

Impact anticipated to be **most significant for SMEs**

1. Economic operator placing the battery on the market
2. High data accuracy is important from all stakeholders, but lacking accuracy most impacts the passport issuer (responsible for the passport) and the data receiver (most dependent on good data to derive insights)
3. SME: small- and medium-sized enterprises
4. MNC: multi-national corporations

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Benefits enabled by the battery passport use cases are likely to outweigh the drawbacks arising from unmitigated challenges

NOT EXHAUSTIVE[1] | Effort required for the implementation | Negative impacts of the implementation | Positive impacts of the implementation

	Drawbacks	vs	Benefits
Economic	**Investment needed** in (IT) infrastructure and (training of) specialists	<	**Cost decrease** enabled by more efficient operations
	Competitive disadvantage of less advanced companies when failing to fulfil responsibilities and requirements	<	**Revenue increase** through new business models and product differentiation for sustainable players and high-quality batteries
Environmental	**Raw materials needed** for additional (IT) infrastructure	<	**Natural resource conservation** achieved through circular processes leading to decreased demand in primary material
	GHG emissions caused by increased energy demand for data exchange and storage	<	**GHG emissions decrease** as a result of building more environmentally friendly and circular value chains
Social	**Tension, stress and additional workload** while implementing and transitioning	<	**Increase in health and safety** through data availability decreasing accidents and risks caused by defective batteries
	Digital divide in the case of unequal access to digital infrastructure, devices or digital literacy	<	**Strengthened human rights and reduced child labour** through more transparent supply chain due diligence
	Job displacement of lower-skilled jobs that become automated or unnecessary	<	**Job creation** through digital transformation leading to generation of higher skilled jobs

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

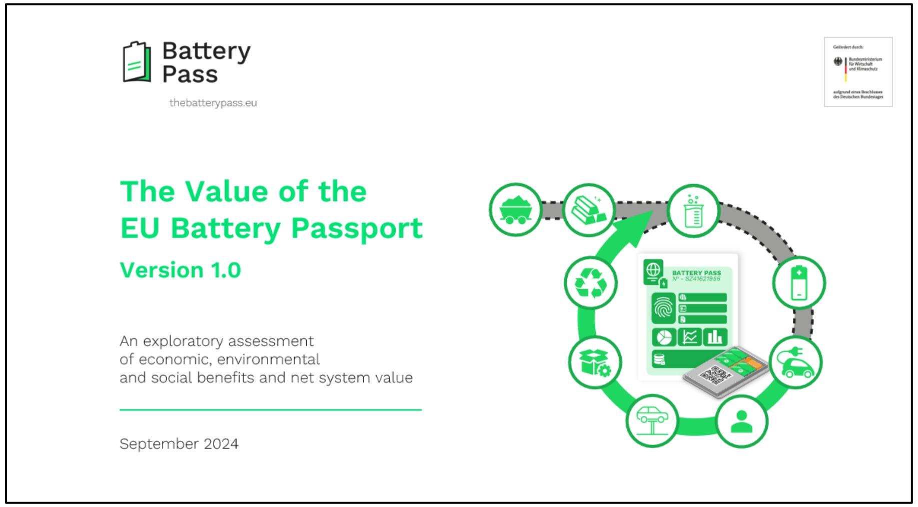
Chapter 6: Outlook and acknowledgements

The Battery Pass will continue the value assessment by analysing the net system value of the battery passport

PRELIMINARY AND NOT EXHAUSTIVE

1. Qualitative-conceptual evaluation of systemic perspective of battery passport and its multiple use cases and impacts
2. Quantification of aggregated benefit potentials
3. Consideration of net impacts including drawbacks and requirements

Assessment of systemic value


Battery Pass
thebatterypass.eu

The Value of the EU Battery Passport
Version 1.0

An exploratory assessment of economic, environmental and social benefits and net system value

September 2024

To be released September 2024

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Battery Pass

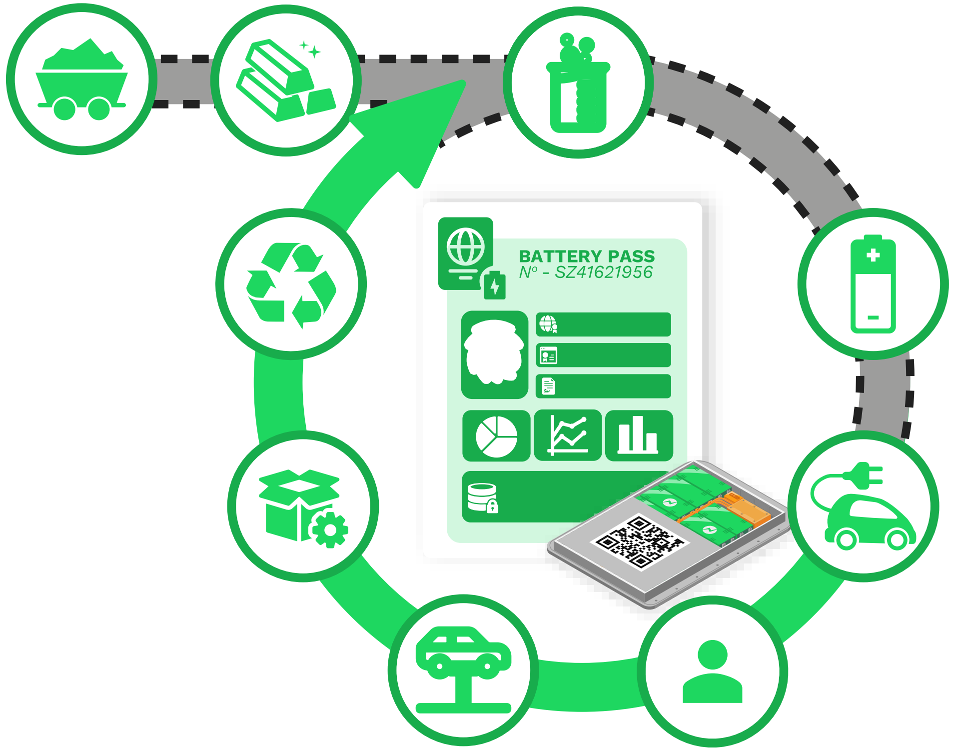
thebatterypass.eu

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

The Value of the EU Battery Passport

Version 1.0

An exploratory assessment
of economic, environmental
and social benefits and net system value



September 2024

Acknowledgements

Authors

Lead:
Sophie Herrmann
Niklas Niemann
Tilmann Vahle
Stephanie Schenk
Anna Braunfels
Achim Teuber

Working Group:
Johannes Simböck
Lisa Risch
Manuela Hafner
Hannes Schneider
Matthias Simolka
Jelto Folkerts
Patrick Zank
Deike Ihnen
Gernot Böge
Karen Vega
Niko D'Agostino
Sven Jantzen

Contributors

The authors would like to thank all organisations contributing to this assessment for their time and knowledge.

37 industrial companies

10 research organisations

3 subject matter experts

11 service companies

2 not-for-profit organisations

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Annex

- Overview of mandatory battery passport information
- Technical Appendix "More Efficient Recycling"
- Technical Appendix "Simplified residual determination"
- Technical Appendix "Increased EOL collection"
- Use case by use case analysis on differences for industrial batteries

The scope of the battery passport goes beyond existing reporting requirements from the Battery Regulation

Reporting of information required for:

Battery Regulation independent from battery passport AND in battery passport

Attribute	Number
Battery unique identifier	1
Manufacturer's identification	2
Manufacturing date and place	3-4
Battery category and weight	5
EU declaration of conformity, ID of EU declaration of conformity, Results of tests reports	8- 10
Separate collection symbol, Meaning of labels and symbols, Cadmium and lead symbols	11-13
Critical raw materials	14
Battery chemistry	15
Hazardous substances: Name, Hazard classes and/or categories, Related identifiers, Location, Concentration range	19-23
Impact of substances on the environment, human health, safety	24
Battery carbon footprint (CF): Share of CF/life cycle stage (raw material acquisition and pre-processing; main product production; distribution; EOL and recycling); CF performance class, Web link to public CF study	25-31
Information of the due diligence report	32
Extinguishing agent, safety measures/instructions	42-43
Pre-consumer recycled: nickel, cobalt, lithium, lead, nickel share	44-47
Post-consumer recycled: nickel, cobalt, lithium, lead, nickel share	48-51

Attribute	Number
Role of end-users in contributing to: waste prevention and the separate collection of waste batteries	53-54
Information on separate collection, take-back, collection points and preparing for re-use, preparing for repurposing and recycling operations	55
State of certified energy (SOCE)	58
Self-discharging rates: Initial, current, evolution of	59-61
Rated capacity, Capacity fade	62, 64
Original power capability, Power capability fade	69, 71
Round trip energy efficiency: Initial and at 50% of cycle-life, Remaining round trip energy efficiency, Round trip energy efficiency fade	74-77
Initial internal resistance on battery cell level, on battery pack level	78, 81
Expected lifetime: Number of charge-discharge cycles	86
Number of (full) charge-discharge cycles	87
Energy and Capacity throughput	90-91
Date of putting the battery into service	95
Time spent: • In extreme temperatures above and below boundary • Charging during extreme temperatures above and below boundary	98-101

Only in battery passport

Attribute	Number
Battery status	7
Cathode, anode, electrolyte materials: Name, Related identifiers, Weight	16-18
Manual for: • Removal of the battery from the appliance • Disassembly and dismantling of the battery pack	36-37
Sources for spare parts: postal, e-mail and web address	38-40
Part numbers for components	41
Renewable content share	52
Nominal, minimum and maximum voltage	66-68
State of Charge (SoC)	65
Maximum permitted battery power	72
Cycle-life reference test	88
C-rate of relevant cycle-life test	89
Capacity threshold for exhaustion	92
Warranty period of the battery	94
Temperature range idle state (lower and upper boundary)	96-97
Information on accidents	102

1. Data attribute number as indicated in the Battery Passport Attribute Longlist (Battery Pass consortium (2023c)); voluntary data attributes added by the Battery Pass consortium not displayed, therefore gaps in the numbering occur

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Annex

- Overview of mandatory battery passport information
- Technical Appendix "More Efficient Recycling"
- Technical Appendix "Simplified residual determination"
- Technical Appendix "Increased EOL collection"
- Use case by use case analysis on differences for industrial batteries

Technical annex recycling case (1/2)

ONLY MAIN INPUTS

Input / Source

Cost of recycling

Recycling process cost	[EUR/kg]
Sampling & sorting (information via sampling)	0.32-0.64 €
Sampling & sorting (selective information from seller)	0.16-0.32 €
Dismantling	1.08 €
Mechanical-hydrometallurgical treatment	5.48 €

Source: Sorting and sampling assumptions based on expert interviews. Other process cost based on generic recycling cost model from Argonne National Laboratory (2023)

Battery passport scenario assumptions

Scenario assumptions	Minimum [%]	Maximum [%]
Increase in materials recovered	1%	2%
Reduction of sampling cost	50%	80%
Reduction of dismantling cost (process improvement)	20%	40%
Reduction of dismantling cost (process automation)	20%	30%
Reduction of recycling treatment cost (material and process cost only)	10%	20%

Source: Expert interviews

Material per battery chemistry

NMC (111)	Material composition [kg/kg]
Lithium	0.03
Cobalt	0.08
Nickel	0.08
Manganese	0.07
Copper	0.17
Aluminium	0.09
Graphite	0.20
Plastics	0.02
Electrolyte organics	0.09
Anode binder	0.01
Others	0.39

NMC (622)	Material composition [kg/kg]
Lithium	0.03
Cobalt	0.04
Nickel	0.13
Manganese	0.04
Copper	0.18
Aluminium	0.09
Graphite	0.22
Plastics	0.02
Electrolyte organics	0.09
Anode binder	0.00
Others	0.36

Source: Argonne National Laboratory (2023)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Technical annex recycling case (2/2)

ONLY MAIN INPUTS

Input			Source
Recovery rate (per active material)	**Active material**	**Recovery rate [%]**	EU minimum recovery targets from 2031 as defined in the Battery Regulation (European Commission (2023a)) and values provided in the EverBatt model by the Argonne National Laboratory (2023)
	Cobalt	95.00%	
	Graphite	0.00%	
	Iron	0.00%	
	Lithium	80.00%	
	Manganese	80.00%	
	Nickel	95.00%	
	Sodium	0.00%	
CO_2 footprint of virgin materials	**Active material**	**[kg CO_2 eq. / kg]**	Global market activities retrieved from Ecoinvent (2024), cut-off cumulative LCIA v.3.91.1.
	Cobalt	44.89863483	
	Graphite	3.979205596	
	Iron-sulfate	0.159597627	
	Lithium	79.05499404	
	Manganese	5.503760567	
	Nickel	17.38794333	
	Sodium	2.01125836	
CO_2 reduction rate by recycling	CO_2 reduction rate by recycling for active materials [%]: 39%		Rinne et al. (2021)

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Annex

- Overview of mandatory battery passport information
- Technical Appendix "More Efficient Recycling"
- Technical Appendix "Simplified residual determination"
- Technical Appendix "Increased EOL collection"
- Use case by use case analysis on differences for industrial batteries

Technical annex residual value determination case (1/2)

ONLY MAIN INPUTS

Input | **Source**

Average price of second-life battery

[EUR/kWh]	2023	2026	2030	2035	2040
Price	113	91	70	60	50

Source: Own convictions based on Global Sustainable Electricity Partnership (2021)

Original capacity (per battery type)

[kWh]	2020	2025	2030
BEV	54	68	72
PHEV	13	15	19

Source: Own convictions based on IHS Markit forecast via T&E (2021) and Xu et al. (2022)

Modules per pack

Modules per pack [amount]: 8

Source: Samsung SDI (2016)

Modules tested in scenarios

[%]	2020
Inhouse sourcing	0
Direct sourcing	1
Inhouse sourcing	2

Source: Assumption based on expert interviews

Technical assessment costs

[Euro/Module tested]	Min	Max
Capacity and energy testing	750	2500
Internal resistance testing	250	833
SOC/OCV testing	2000	6667
Technical assessment cost	3000	10000
	One temperature	3 temperatures

Source: Assumption based on expert interview; test cost breakdown educated guess from industry expert based on time needed for respective tests

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Technical annex residual value determination case (2/2)

ONLY MAIN INPUTS

Input		Source
Baseline share of batteries going into second-life	see table below	Own convictions based on data from CES (2023)
Average remaining capacity	Average remaining capacity [%]: 70	Assumption based on expert interviews
Active materials needed for LFP battery	see table below	Own convictions based on Leader et al. (2019), IEA (2023a) and IDTechEx (2021), assuming 10% material intensity decrease in 10 years
CO_2 footprint of primary active materials	see table below	Global market activities retrieved from Ecoinvent (2024), cut-off cumulative LCIA v.3.91.1.

Baseline share of batteries going into second-life

[%]	2023	2025	2030
Repurposing	9%	9%	15%
Remanufacturing	1%	1%	2%
SUM	10%	10%	17%

Active materials needed for LFP battery

[kg/kWh]	Graphite	Iron	Lithium
LFP	0.8	0.77	0.1

CO_2 footprint of primary active materials

Active material	[kg CO2 eq. / kg]
Cobalt	44.89863483
Graphite	3.979205596
Iron-sulfate	0.159597627
Lithium	79.05499404
Manganese	5.503760567
Nickel	17.38794333
Sodium	2.01125836

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Annex

- Overview of mandatory battery passport information
- Technical Appendix "More Efficient Recycling"
- Technical Appendix "Simplified residual determination"
- Technical Appendix "Increased EOL collection"
- Use case by use case analysis on differences for industrial batteries

Technical annex collection case (1/2)

ONLY MAIN INPUTS

Input / Source

Vehicle outflow (de-registered vehicles)

Vehicles leaving European roads [number]: 12 mn

Source: Heinrich Böll Stiftung (2021)

Electric vehicle share

[%]	2020	2025	2030
EV sales share	10	33	64

Source: IEA (2023b): APS scenario

Capacity (per battery type)

[kWh]	2020	2025	2030
BEV	54	68	72
PHEV	13	15	19

Source: Own convictions based on IHS Markit forecast via T&E (2021) and Xu et al. (2022)

Battery chemistry market share

[%]	2020	2030	2040	2050
Na-ion	0%	4%	16%	20%
LNMO	0%	7%	9%	13%
LFP	20%	49%	36%	35%
LNO	0%	3%	8%	10%
LMR-NMC	0%	6%	8%	9%
NMC-highNi	25%	18%	12%	5%
NMC-medNi	40%	2%	0%	0%
NMC-lowNi	0%	0%	0%	0%
NMCA	0%	7%	5%	4%
NCA+	15%	6%	7%	5%

Source: Average of "baseline" and "high efficiency" scenarios from Energy Transition Commission (2023)

Active material intensity (per chemistry)

[kg/kWh]	Cobalt	Graphite	Iron-batteries	Lithium	Manganese	Nickel	Sodium
Na-ion	0	1.1	0.7	0	0	0	0.3
LNMO	0	0.7	0	0.05	0.75	0.25	0
LFP	0	0.8	0.77	0.1	0	0	0
LNO	0	0.7	0	0.1	0	0.8	0
LMR-NMC	0.08	0.93	0	0.1	0.4	0.13	0
NMC-highNi	0.076	0.8	0	0.09	0.071	0.608	0
NMC-medNi	0.17	0.8	0	0.1	0.159	0.508	0
NMC-lowNi	0.313	0.8	0	0.118	0.292	0.312	0
NMCA	0.05	0.7	0	0.1	0.05	0.7	0
NCA+	0.117	0.8	0	0.106	0	0.618	0

Source: Own convictions based on Leader et al. (2019), IEA (2023a) and IDTechEx (2021), assuming 10% material intensity decrease in 10 years

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Technical annex collection case (2/2)

ONLY MAIN INPUTS

Input			Source
Share of unknown whereabouts (illegal exports, illegal treatment and other)	Scenario I: Business as Usual [Share]: 37 %	Scenario II: More Control [Share]: 20%	Umweltbundesamt (2020) and ADEME (2019)

Recovery rate (per active material)

Active material	Recovery rate [%]
Cobalt	95.00%
Graphite	0.00%
Iron	0.00%
Lithium	80.00%
Manganese	80.00%
Nickel	95.00%
Sodium	0.00%

Source: EU minimum recovery targets from 2031 as defined in the Battery Regulation (European Commission (2023a)) and values provided in the EverBatt model by the Argonne National Laboratory (2023)

Commodity prices

Active material	Price[EUR/kg]
Cobalt	51.13 €
Graphite	1.22 €
Iron	0.30 €
Lithium	21.73 €
Manganese	1.05 €
Nickel	15.48 €
Sodium	2.79 €

Source: 5-year averages from DERA (2023)

CO_2 footprint of primary active materials

Active material	[kg CO2 eq. / kg]
Cobalt	44.89863483
Graphite	3.979205596
Iron-sulfate	0.159597627
Lithium	79.05499404
Manganese	5.503760567
Nickel	17.38794333
Sodium	2.01125836

Source: Global market activities retrieved from Ecoinvent (2024), cut-off cumulative LCIA v.3.91.1.

Input		Source
CO_2 reduction rate by recycling	For active materials [%]: 39%	Rinne et al. (2021)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Annex

- Overview of mandatory battery passport information
- Technical Appendix "More Efficient Recycling"
- Technical Appendix "Simplified residual determination"
- Technical Appendix "Increased EOL collection"
- Use case by use case analysis on differences for industrial batteries

A Reliable communication of ESG data

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

For industrial batteries, the **overall benefits regarding reliable communication of ESG data remain consistent.** In the case of **batteries with external storage**, the **key aspects** of the general use case scenario could be **leveraged at a later time or on a voluntary basis.**

Overall applicability:

All industrial batteries (Equally applicable)

Key differences compared to general use case

Due diligence report	**No differences:** Equally required for battery passport for all industrial batteries.
Carbon footprint (in total and share per life cycle stage)	**Reporting will be mandatory 54 months later for industrial batteries with external storage** (redox-flow-batteries) compared to all other industrial batteries.
Recycled content shares	**Reporting not required for industrial batteries with external storage[1]** (redox-flow-batteries) and for (industrial) **batteries that do not contain cobalt, lithium, nickel or lead** in active materials (e.g. sodium sulphur, sodium-ion batteries).

Applicability of general battery passport benefits

Use case benefits equally applicable: The significant aspects of due **diligence requirements are identical** for all batteries and do not change the benefits assessment.

Use case benefits equally applicable (only later for batteries with external storage): For the carbon footprint information there is only a **delay in the timeline of applicability** (54 months) for industrial batteries with external storage. Thus, benefits regarding CF reporting will not significantly deviate **for industrial batteries**.

Use case benefits largely equally applicable: If economic operators **voluntarily provide information** on the share of recycled content, they may **enhance their market positioning** and unlock the benefits outlined in the general use case.

See details of general use case on slide 50

1. Batteries with external storage have additional notable system distinctions with regard to servicing which fall beyond the scope of this analysis (see excursus on slide 115)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

B Informed purchasing decisions

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

The **battery passport supports informed purchasing decisions for industrial batteries with BMS/connectivity**, offering analogous benefits to the general use case. **The applicability is reduced for industrial batteries without BMS/connectivity** as they lack detailed dynamic data that can inform purchasing decisions **after a usage period**.

Overall applicability:

- ✓ Industrial batteries with BMS
- – Industrial batteries without BMS

Key differences compared to general use case

Aspect	Key differences compared to general use case	Applicability of general battery passport benefits
Business relations	In the context of industrial batteries, **purchasers are often distinct from ultimate end-users** (e.g. within a company distinction between buyer and forklift operator). Alternatively, there may be **intermediaries**, e.g. when an installer acquires a home storage system and subsequently sells it to the homeowner, though these processes vary internationally.	**Use case benefits equally applicable: Although processes differ** and there may be divergent interests on the part of buyers and end-users, **the battery passport could enable an informed purchasing decision for all new industrial batteries**.
Performance and durability data	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial batteries than stationary battery energy storage systems** (SBESS).	**Use case benefits equally applicable:** The information requirements deviate only little compared to the overall scope of performance and durability data. Thus, the **impact on the benefits is negligibly small**.
Share of recycled content **Carbon footprint** **Due diligence report**	See use case “Reliable communication of ESG data”	**Use case benefits largely equally applicable:** Use case “**Reliable communication of ESG data**” is largely equally applicable to industrial batteries, therefore the **benefits regarding informed purchasing decision** associated with these data attributes **remain consistent** with the general use case.
Battery chemistry	**No differences:** Equally required for battery passport for all industrial batteries.	**Use case benefits equally applicable:** Battery chemistry is available as **part of an informed purchasing decision for all industrial batteries.**
Second life/Recycling	**Industrial batteries are mostly directly recycled** and there is currently no significant market for trading used industrial batteries (e.g. for second-life) except for transfer of ownership within the same application.	**Use case benefits equally applicable:** The battery passport supports an informed purchasing decision for used industrial batteries, with recyclers representing the main buyers of used/waste industrial batteries.
Performance and durability data	**Not available for industrial batteries without a battery management system** (BMS).	**Use case benefits less applicable for used industrial batteries without BMS: Dynamic data** are not available for used industrial batteries without BMS, thus they **cannot be used for an informed purchasing decision.**

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

C Eased servicing

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

Battery passport data could facilitate inhouse servicing and predictive maintenance for industrial batteries. **Yet, benefits for servicing through independent workshops is less applicable** because of predefined service contracts or processes that are predominant for most industrial batteries. Moreover, **benefits arising from dynamic data do not apply to industrial batteries without BMS/connectivity.**

Overall applicability:

— All industrial batteries

Key differences compared to general use case

Maintenance Business Relations	Maintenance or repair **services for industrial batteries are typically included as** a component of (inhouse) service **contracts between** the **manufacturer and the B2B client or end-user** of the machinery (e.g. electric logistic solutions and large-scale SBESS). **Also, for B2B relations** (e.g. home storage), **typically services** are only **conducted by the manufacturer or authorised actors**.
Performance and durability data	**Not available for industrial batteries without a battery management system/connectivity** (BMS).
Maintenance with/without BMS	Repairing Li-ion (and other) batteries with a BMS requires specialised knowledge, tools and attention to safety, whereby dynamic data is beneficial. Batteries **without a BMS generally involve simpler repairing and maintenance with little promise of improvements through dynamic data**.
Performance and durability data e.g. negative events	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial batteries than stationary battery energy storage systems** (SBESS).
Dismantling information	**No differences:** Equally required for battery passport for all industrial batteries.

Applicability of general battery passport benefits

Use case benefits less applicable for most industrial batteries[1]: Since servicing is a core business case for manufacturers of industrial batteries, **benefits for independent workshops are likely to be relatively small.** Nevertheless, battery passport data could be used to **ease inhouse servicing and predictive maintenance** to a certain extent (more detailed data is needed for more profound insights).

Use case benefits not applicable for industrial batteries without BMS: For industrial batteries **without a BMS**, dynamic data is currently not available and would promise comparatively **little economic benefits** to facilitate repairing and predictive maintenance, also considering high investments needed to enable dynamic data flows for batteries without a BMS.

Use case benefits equally applicable: The information requirements deviate little compared to the overall scope of performance and durability data. Thus, the **impact on the benefits is negligibly small**.

Use case benefits equally applicable: Since dismantling information is required for all industrial battery subgroups, it is **equally available for eased servicing of industrial batteries.**

See details of general use case on slide 52

1. Batteries with external storage have additional notable system distinctions with regard to servicing which fall beyond the scope of this analysis (see excursus on slide 115)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

D Precise risk assessment for transport of used/ waste batteries

Applications / Market
Chemistry / Technology
§ Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

The risk assessment for transportation of used/waste batteries with BMS benefits from dynamic data via the battery passport independent of battery category and the **use case** is therefore **equally applicable to industrial batteries with BMS**. The **risk assessment of industrial batteries without a BMS** (e.g. Pb-acid, Ni-based) is less complex and **does not require dynamic data** via the battery passport. **Transportation restrictions differ for batteries with external storage** and **benefits** from battery passport data **do not apply.**

Overall applicability:

- Equally applicable: Industrial batteries with BMS
- Less applicable: Industrial batteries without BMS
- Not applicable: Industrial batteries with external storage

Key differences compared to general use case

§ **Performance and durability data** e.g. capacity fade, negative events	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial batteries than stationary battery energy storage systems** (SBESS).
Performance and durability data	**Dynamic data not available for industrial batteries without a battery management system** (BMS).
Transport by Chemistry / Technology	Some industrial batteries (**lead-acid, nickel-based**), could already be **transported without a complex risk assessment**. The requirements differ regarding battery chemistry and the classification of hazardous substances. Only components of **industrial batteries with external storage** are transported and **carry less risks** than other batteries.

Applicability of general battery passport benefits

Use case benefits equally applicable: The available data could help create a precise risk assessment prior to transportation, although additional data points and definitions would be beneficial (e.g. definition of an accident in the context of industrial batteries, documents such as UN38.3 safety measures).

Use case benefits less applicable for industrial batteries without BMS: Battery cell chemistries, which do not have a BMS, have risk assessment methods defined by the transport regulations (e.g. ADR) that are **sufficient to ensure safe transport even without dynamic performance data**. However, static information on battery chemistry and performance, e.g. capacity provide a benefit.

Use case benefits are not applicable for industrial batteries with external storage (redox-flow): Transportation restrictions differ for batteries with external storage and benefits from battery passport data do not apply.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

E More efficient recycling processes

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

The use case for **more efficient recycling processes is applicable to batteries with Li-ion or emerging chemistries independent of battery category.** Handling of **other battery chemistries** such as Pb-acid, NiMH or those in batteries with external storage, however, **do not need advanced sampling or complex dismantling**, so that the data contained in the battery passport offers **less added value.**

Overall applicability:

- ✓ Industrial batteries with Li-ion and emerging chemistries
- – Industrial batteries except Li-Ion and emerging chemistries

Key differences compared to general use case

Need for sampling	**Lithium-ion batteries** and those with **emerging chemistries** currently require sampling **to prevent negative impact** on recycling **processes**. **In contrast, lead-acid, nickel-based** batteries and batteries with external storage (**redox-flow)**[1] do not require advanced sampling due to their respective chemical homogeneity**.**
Battery composition	**No differences:** Equally required for battery passport for all batteries.
Dismantling process	**The dismantling process for lead-acid, nickel-based** batteries and batteries with external storage (**redox-flow)**[1] is less complex than for lithium-ion and other emerging chemistries.
Dismantling information	**No differences:** Equally required for battery passport for all batteries.

Applicability of general battery passport benefits

Use case benefits less applicable to industrial batteries with chemistries such as Pb-acid, NiMH or those in batteries with external storage: Recycling processes for those battery chemistries do **not require advanced sampling.**

Use case benefits equally applicable for lithium-ion (and emerging chemistries, such as sodium-ion): Recycling processes require advanced sampling.

Use case benefits less applicable to industrial batteries with chemistries such as Pb-acid, NiMH or those in batteries with external storage: Dismantling information provides less advantage for those battery chemistries as the battery dismantling process is less complex. Use case benefits equally applicable for lithium-ion (and emerging chemistries, such as sodium-ion: Established and future recycling processes could become more efficient through more automated dismantling and known battery composition).

See details of general use case on slide 54

1. Batteries with external storage have additional notable system distinctions with regard to servicing which fall beyond the scope of this analysis (see excursus on slide 115)

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

F Simplified residual value determination

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

Due to more exhaustive service lives of **industrial batteries,** they are **rarely used in second life applications.** Therefore, the **residual value determination** is **only needed for transfer of ownership within the same application, which limits the applicability of the use case.** Exceptions could be heavy duty applications, e.g. in agriculture & construction. Additionally, the **absence of dynamic data for industrial batteries without a BMS/connectivity limits the potential of the use case** further for this subgroup.

Overall applicability:

– All industrial batteries

Key differences compared to general use case

Business cases	Due to the load cycles and overall lifespan of most **industrial batteries,** they will have a **lower SoH or capacity at the end of their service life.** For instance, forklift batteries and SBESS are often used until they could no longer be repurposed. Potential business cases for residual value determination of industrial batteries include remanufacturing, insurance matters, **transfer of ownership**, with the latter the **most likely.**
Performance and durability data	**Not available for industrial batteries without a battery management system** (BMS).
Performance and durability data e.g. capacity fade, negative events	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial Batteries than Stationary Battery Energy Storage Systems** (SBESS).
Battery chemistry and composition	**No differences:** Equally required for battery passport for all industrial batteries.

Applicability of general battery passport benefits

Use case benefits less applicable for most industrial batteries: Because of reduced availability of industrial for a second life, the market for residual value determination will be relatively small (compared to EV batteries) with **fewer benefits to be gained via the battery passport.**

Use case benefits not applicable for industrial batteries without a BMS: Due to the missing BMS and the inability to save the values required to determine the residual value, **the cost to enable a residual value determination is offset by the efficient recycling processes already in place.** As these batteries could be operated up to a SoH of 20-30%, recycling is more likely than resale.

Use case benefits equally applicable: The information requirements deviate little compared to the overall scope of performance and durability data and the **impact on the benefits is negligible.** For batteries with external storage (redox-flow-batteries), chemistry provides decisive information about the durability and residual value of the electrolyte (see excursus).

Use case benefits equally applicable: Battery chemistry and composition is **available as part of a simplified residual value determination for all industrial batteries.**

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

See details of general use case on slide 55

G Streamlined trade of used/waste batteries through marketplaces

Applications / Market
Chemistry / Technology
§ Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

The **battery passport could be leveraged for streamlined trade of used/waste batteries through marketplaces equally for industrial batteries**. The different handling of batteries downstream, where these batteries are typically directly recycled rather than re-used or repurposed does not affect the benefits of their streamlined trade.

Overall applicability:

All industrial batteries

Key differences compared to general use case

Use phase downstream	**Most industrial batteries are directly recycled** after their first life and there is no significant market for repurposing.
Battery composition	**No differences:** Equally required for battery passport for all industrial batteries.
Performance and durability data	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial batteries than stationary battery energy storage systems** (SBESS).
Performance and durability data	**Not available for industrial batteries without a battery management system** (BMS).

Applicability of general battery passport benefits

Use case benefits equally applicable: Like other batteries, industrial batteries could also be traded via a marketplace. However, due to the low probability of a second life, **marketplaces might be especially relevant for trading used batteries for recyclers.**

Use case benefits equally applicable: Battery composition of all industrial batteries **could be made available as information for recyclers on marketplaces.**

Use case benefits equally applicable: The **information requirements deviate little** compared to the overall scope of performance and durability data and the **impact on the benefits is negligible.**

Use case benefits equally applicable: The **differences in data availability do not have an impact on** the **benefits of streamlined trading** of used batteries, **since for the same chemistry/technology subgroups, consistent information is expected to be available** (e.g. lead-acid batteries are expected to be compared with other lead-acid batteries on marketplaces, thus missing dynamic data have no impact).

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

See details of general use case on slide 56

H Efficient data exchange and reporting based on upstream traceability

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

Battery passport data requirements that could be **fulfilled through a traceability system enable a more transparent supply chain equally for all industrial batteries**, with negligible differences compared to the general analysis of this use case.

Overall applicability:

All industrial batteries

Key differences compared to general use case

Due diligence report	**No differences:** Equally required for battery passport for all industrial batteries.
Carbon footprint (in total and share per life cycle stage)	Reporting will be **mandatory 54 months later for industrial batteries with external storage** (redox-flow-batteries) compared to all other industrial batteries.
Recycled content shares	Reporting **not required for industrial batteries with external storage** (redox-flow-batteries) and for (industrial) **batteries that do not contain cobalt, lithium, nickel or lead** in active materials (e.g. sodium sulphur, sodium-ion batteries).

Applicability of general battery passport benefits

Use case benefits equally applicable: The significant aspects of due **diligence requirements** are identical for all batteries and **do not change the benefits assessment**.

Use case benefits equally applicable (only later for batteries with external storage): For the carbon footprint information there is only a **delay in the timeline of applicability** (54 months) for industrial batteries with external storage. Thus, **benefits** regarding CF reporting **will not significantly deviate for industrial batteries**.

Use case benefits equally applicable: The differences regarding recycled content have very little impact on the overall benefits assessment. **In the absence of recycled content requirements, supply chain management is still a valid use case** due to the significant scope of due diligence and carbon footprint requirements.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

See details of general use case on slide 86

I Increased end-of-life collection

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

For industrial batteries, **predetermined and monitored take-back processes** already result in a **higher collection rate** compared to EV batteries. Additionally, the **bulkiness and immobility** of many industrial batteries serve as **barriers to illegal exports**. Consequently, the **potential use case of increased end-of-life collection**, facilitated by additional non-mandatory information on the battery passport, is **less applicable to industrial batteries**.

Overall applicability:

– All industrial batteries

Key differences compared to general use case

B2B Collection	In the case of **B2B collections**, e.g. used forklift batteries, the **return of the battery is often contractually regulated at the time of purchase**, so that a leak or **illegal export** of the products is **less likely**.
B2C Collection	In the case of B2C collection, e.g. of home storage systems, batteries must be registered in advance by the manufacturer or retailer in waste management organisations (e.g. EAR in Germany). As soon as end-users want to return the batteries, they are able to contact the manufacturer or retailer, who will then initiate the take-back process, with **B2C processes** more variable compared to B2B. A leak or **illegal export** of home storage systems is **less likely** (compared to EVs) **due to their complex installation and stationary use**, and due to **well-defined take back processes.**
Performance and durability data	**Not available for industrial batteries without a battery management system** (BMS).
Additional information (e.g. date of export)	**No differences:** Equally possible to include additional voluntary information for all industrial batteries in battery passport.

Applicability of general battery passport benefits

Use case benefits less applicable for industrial batteries: As fewer illegal exports are generally to be expected for industrial batteries, the corresponding **benefits that the battery passport could enable are limited**.

For home storage systems, where take-back processes are more variable than B2B processes, the **battery passport could offer an additional benefit in raising awareness of the need to return no longer used home storage batteries** and the associated valuable materials (instead of leaving them in the basement, e.g.) – which in turn could lead to an increased end-of-life collection.

Use case benefits less applicable for industrial batteries without a BMS: Industrial batteries without a BMS are **missing information relating to their State of Health, further limiting the benefits**.

Use case benefits equally applicable: Additional information could **help export control and market surveillance also for industrial batteries**.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

J Industry benchmarking

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

Aggregated data could enable benchmarking of industrial batteries **with benefits** of the general use case **remaining consistent for industrial batteries with BMS.** However, n**o benchmarking of detailed dynamic performance data** is possible for batteries **without BMS/connectivity**.

Overall applicability:

- Equally applicable: Industrial batteries with BMS
- Less applicable: Industrial batteries without BMS

Key differences compared to general use case

§ **Share of recycled content** **Carbon footprint** **Due diligence report**	See use case "Reliable communication of ESG data"
§ **Performance and durability data**	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial batteries than stationary battery energy storage systems** (SBESS).
Chemistry / Technology: **Performance and durability data**	**Not available for industrial batteries without a battery management system** (BMS)/connectivity.

Applicability of general battery passport benefits

Use case benefits largely equally applicable: Use case "Reliable Communication of ESG data" is equally applicable to industrial batteries. Therefore, **aggregating those data attributes could enable industry benchmarking also for industrial batteries** and the benefits of the general use case are largely equally applicable to industrial batteries.

Use case benefits equally applicable: The **information requirements deviate little** compared to the overall scope of performance and durability data. Thus, the **impact on the benefits is negligibly small.**

Benefits not applicable for industrial batteries without BMS: Dynamic performance and durability data are not available for industrial batteries without BMS, thereby **benchmarking of dynamic performance data is not possible for this subgroup** (e.g. aging of a certain battery across various applications cannot be compared).

Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

See details of general use case on slide 107

K Accurate market overview

Applications / Market
Chemistry / Technology
Requirements per EU Battery Regulation

(Use case) Equally applicable
Less applicable
Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

Aggregating data of battery passports **could enable an accurate market overview** equally **for industrial batteries with BMS,** with negligible variations in data availability. However, a **detailed market overview specifically relating to batteries' conditions** (e.g. state of health) is **not available for industrial batteries without BMS/connectivity.**

Overall applicability:

- Industrial batteries with BMS: Equally applicable
- Industrial batteries without BMS: Less applicable

Key differences compared to general use case

General information	**No differences:** Equally required for battery passport for all industrial batteries.
Materials and composition	**No differences:** Equally required for battery passport for all industrial batteries
Performance and durability data	Slightly **fewer dynamic data required** for battery passport (i.e. Art. 14/Annex VII vs Art. 10/Annex IV and XIII.) **for other industrial batteries than stationary battery energy storage systems** (SBESS).
Recycled content shares	Reporting **not required for industrial batteries with external storage** (redox-flow-batteries) and for (industrial) **batteries that do not contain cobalt, lithium, nickel or lead** in active materials (e.g. sodium sulphur, sodium-ion batteries).
Performance and durability data	**Not available for industrial batteries without a battery management system** (BMS)/connectivity.

Applicability of general battery passport benefits

Use case benefits equally applicable: Though there are **slight variations in the availability of information** for industrial batteries, they **deviate little compared to the overall data available within the scope of this use case**. As a result, the impact on the benefits is negligibly small.

Use case benefits not applicable for industrial batteries without BMS: An **accurate market overview including dynamic data** of the service life (e.g. state of health) and the associated benefits are **not applicable for industrial batteries without BMS**.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

See details of general use case on slide 108

L Informed policy design

- Applications / Market
- Chemistry / Technology
- § Requirements per EU Battery Regulation
- ✓ (Use case) Equally applicable
- — Less applicable
- X Not applicable

Use case analysis specific to industrial batteries with capacity > 2 kWh

Key takeaway

Almost all battery pass data attributes could contribute to this use case. **Overall**, the **data availability** deviates **little for industrial batteries** with negligible impact on the use case benefits. Therefore, **informed policy design enabled through aggregating passport data applies equally to all industrial batteries.** Given the broader variance in industrial applications, **additional differentiation in application-specific information would add further benefits to this use case.**

Overall applicability:

✓ All industrial batteries

Key differences compared to general use case

Variance applications	Industrial batteries are characterised by a **broad range of different applications** that have different characteristics and service life patterns.
§ **General information**	**No differences:** Equally required for battery passport for all industrial batteries.
§ **Materials and composition**	**No differences:** Equally required for battery passport for all industrial batteries.
§ **Share of recycled content** **Carbon footprint** **Due diligence report**	See use case "Reliable communication of ESG data"
Performance and durability data	**Not available for industrial batteries without a battery management system** (BMS).

Applicability of general battery passport benefits

Use case benefits equally applicable: While informed policy design through the battery passport is equally applicable to industrial batteries, it is important to note that to correctly assess industrial batteries, the applications batteries are used in should be considered (e.g. differences in service lives patterns of heavy machinery batteries and forklift batteries). **Applications are not mapped in the battery passport** and it should be assessed how to **consider the subject to enable a more informed policy design**.

Use case benefits equally applicable: This use case comprises almost all battery passport data attributes. Therefore, the **availability of information for industrial batteries deviates little compared to the overall scope of data in the battery passport**. As a result, the **impact on the benefits is negligibly small**.

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

 See details of general use case on slide 109

Sources

All sources used in this document are listed in alphabetical order (1/3)

ADEME (2019): *Final report: Global Overview of Incentive Schemes aiming to bring ELVs through Authorised Processing Channels*, accessible via: https://copperalliance.org/wp-content/uploads/2021/08/global-overview-of-incentive-schemes-for-elvs-2019.pdf, last accessed 29.01.2024

Argonne National Laboratory (2023): *EverBatt: A Closed-loop Battery Recycling Cost and Environmental Impacts Model.* Energy Systems Division, accessible via: https://anl.app.box.com/v/ReCell, last accessed 29.02.2024

Basel Action Network (BAN) (2018): *Holes in the Circular Economy:* WEEE Leakage from Europe, accessible via: https://wiki.ban.org/images/f/f4/Holes_in_the_Circular_Economy-_WEEE_Leakage_from_Europe.pdf, last accessed 29.01.2024

Balakrishnan (2022): *Canada considering 'passport' for EV batteries in bid to apply ESG standards to growing industry,* accessible via: https://thelogic.co/news/exclusive/canada-considering-passport-for-ev-batteries-in-bid-to-apply-esg-standards-to-growing-industry/, last accessed 29.01.2024

Battery Pass consortium (2023a): *Battery Passport Content Guidance*. Achieving compliance with the EU Battery Regulation and increasing sustainability and circularity. Version 1.1., accessible via: https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Content_Guidance.pdf, last accessed 29.01.2024

Battery Pass consortium (2023b): *Battery Carbon Footprint*. Rules for calculating the Carbon Footprint of the 'Distribution' and 'End-of-life and recycling' life cycle stages. In collaboration with the Global Battery Alliance. Version 1.1., accessible via: https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Carbon_Footprint_Rules.pdf, last accessed 29.01.2024

Battery Pass consortium (2023c): *Battery Passport Data Attribute Longlist*. In collaboration with the Global Battery Alliance, accessible via: https://thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Data_Attributes.xlsx, last accessed 29.01.2024

Bernhart et al. (2023): *Second life and recycling: Enabling a circular battery economy*, accessible via: https://www.rolandberger.com/en/Insights/Publications/Second-life-and-recycling-Enabling-a-circular-battery-economy.html, last accessed 29.01.2024

Circular Australia (2023): *Circular Australia welcomes Australian Government digital product passport proposal*, accessible via: https://circularaustralia.com.au/media_articles/237463/, last accessed 29.01.2024

Circular Energy Storage (CES) (2023): CES online, accessible via: https://circularenergystorage.com/ces-online, last accessed 29.01.2024

Council of the European Union (2023): Regulation establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC - Analysis of the final compromise text for an agreement, accessible via: https://www.consilium.europa.eu/media/69109/st16723-en23.pdf, last accessed 29.01.2024

Deutsche Rohstoffagentur (DERA) (2023): *Preismonitor*, accessible via: https://www.deutsche-rohstoffagentur.de/DERA/DE/Produkte/Rohstoffpreise/Preismonitor/preismonitor_node.html, last accessed 29.01.2024

Dunn et al. (2023): *Should high-cobalt EV batteries be repurposed?* Using LCA to assess the impact of technological innovation on the waste hierarchy, in: Journal of Industrial Ecology 27: 1277–1290, accessible via: https://www.researchgate.net/publication/370801519_Should_high-cobalt_EV_batteries_be_repurposed_Using_LCA_to_assess_the_impact_of_technological_innovation_on_the_waste_hierarchy, last accessed 29.01.2024

Ecoinvent (2024): *The Ecoinvent Database*, cut-off cumulative LCIA v.3.91.1., Climate Change; Global Warming Potential (CML v4.8 2016 no LT), accessible via: https://ecoinvent.org/the-ecoinvent-database/, last accessed 29.01.2024

Energy Transition Commission (2023): *Material and Resource Requirements for the Energy Transition*, accessible via: https://www.energy-transitions.org/publications/material-and-resource-energy-transition/, last accessed 29.01.2024

European Commission (2019): *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS*. The European Green Deal, accessible via: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF, last accessed 07.03.2024

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

All sources used in this document are listed in alphabetical order (2/3)

European Commission (2020): *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS*. A new Circular Economy Action Plan. For a cleaner and more competitive Europe, accessible via: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN, last accessed 07.03.2024

European Commission (2021): *COMMISSION STAFF WORKING DOCUMENT EVALUATION of Directive (EC) 2000/53 of 18 September 2000 on end-of-life vehicles*, accessible via: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2021:0060:FIN:EN:PDF, last accessed 29.01.2024

European Commission (2022a): *Towards a green, digital and resilient economy*: Our European Growth Model, accessible via: https://ec.europa.eu/commission/presscorner/detail/en/IP_22_1467, last accessed 29.01.2024

European Commission (2022b): *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*, accessible via: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A0142%3AFIN, last accessed 29.01.2024

European Commission (2023a): *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*, accessible via: https://eur-lex.europa.eu/eli/reg/2023/1542/oj, last accessed 29.01.2024

European Commission (2023b): *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on circularity requirements for vehicle design and on management of end-of-life vehicles, amending Regulations (EU) 2018/858 and 2019/1020 and repealing Directives 2000/53/EC and 2005/64/EC*, accessible via: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52023PC0451, last accessed 29.01.2024

European Commission; Oeko-Institut e.V. (2017): *Assessment of the implementation of Directive 2000/53/EU on end-of-life vehicles (the ELV Directive) with emphasis on the end of life vehicles of unknown whereabouts.* Under the Framework Contract: Assistance to the Commission on technical, socio-economic and cost benefit assessments related to the implementation and further development of EU waste legislation, accessible via: https://op.europa.eu/en/publication-detail/-/publication/1ca32beb-316a-11e8-b5fe-01aa75ed71a1, last accessed 29.01.2024

Fraunhofer ISI (2023): Recycling, accessible via: https://metamarketmonitoring.de/en/recycling/, last accessed 29.01.2024

Garg (2023): *Run-up to World EV Day: Battery passport, an opportunity for India*, accessible via: https://www.downtoearth.org.in/blog/governance/run-up-to-world-ev-day-battery-passport-an-opportunity-for-india-91325, last accessed 29.01.2024

Global Market Insights (2023): *Industrial Traction Battery Market Size - By Chemistry (Lead Acid, Lithium-Ion, Nickel-Based), By Application (Forklift {Class 1, Class 2, Class 3}, Railroads) & Forecast, 2023 – 2032*, accessible via: https://www.gminsights.com/industry-analysis/industrial-traction-battery-market, last accessed 29.01.2024

Global Sustainable Electricity Partnership (2021): *2nd Life Batteries*. A white paper from Storage Technological Community, accessible via: https://www.globalelectricity.org/wp-content/uploads/2022/09/GSEP_SecondLifeBatteries.pdf, last accessed 29.01.2024

GPQI (2023): *Towards a circular economy with the digital product passport*, accessible via: https://www.gpqi.org/news_en-details/towards-a-circular-economy-with-the-digital-product-passport.html, last accessed 29.01.2024

Heinrich Böll Stiftung (2021): *European Mobility Atlas*. Facts and figures about transport and mobility in Europe. 2nd edition, accessible via: https://eu.boell.org/en/European-Mobility-Atlas, last accessed 29.01.2024

IDTechEx (2021): *Analysis of VW's long-term, high-manganese cathode strategy.* Material intensity of key metals, accessible via https://www.electrichybridvehicletechnology.com/features/dtechex-commentary-on-vws-long-term-high-manganese-cathode-strategy.html) last accessed 29.01.2024

International Energy Agency (IEA) (2023a): *Global EV Outlook 2023*. Catching up with climate ambitions, accessible via: https://www.iea.org/reports/global-ev-outlook-2023, last accessed 29.01.2024

International Energy Agency (IEA) (2023b): *Global EV Data Explorer*, accessible via: https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer, last accessed 29.01.2024

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

All sources used in this document are listed in alphabetical order (2/3)

King et al. (2023): *A proposed universal definition of a Digital Product Passport Ecosystem (DPPE): Worldviews, discrete capabilities, stakeholder requirements and concerns,* accessible via https://www.sciencedirect.com/science/article/pii/S0959652622051125#:~:text=Product%20Passports%20have%20been%20proposed,sustainability%20regulations%20(2022)%20(European, last accessed 29.01.2024

Kotak et al. (2021): *End of Electric Vehicle Batteries: Reuse vs. Recycle*, in: Energies 14(8): 2217, accessible via: https://www.mdpi.com/1996-1073/14/8/2217, last accessed 29.01.2024

Leader et al. (2019): *The effect of critical material prices on the competitiveness of clean energy technologies*, in: Materials for Renewable and Sustainable Energy 8(2): 8, accessible via: https://link.springer.com/article/10.1007/s40243-019-0146-z#Sec19, last accessed 29.01.2024

McKinsey & Company (2023): *Battery 2030: Resilient, sustainable, and circular*. Battery demand is growing – and so is the need for better solutions along the value chain, accessible via: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular, last accessed 29.01.2024

Rinne et al. (2021): *Simulation-based life cycle assessment for hydrometallurgical recycling of mixed LIB and NiMH waste, accessible via:* https://www.sciencedirect.com/science/article/pii/S0921344921001956?via%3Dihub, last accessed 29.01.2024

Samsung SDI (2016): *The Composition of EV batteries: Cells? Modules? Packs? Let's Understand Properly, accessible via:* https://www.samsungsdi.com/column/all/detail/54344.html#:~:text=Twelve%20cells%20are%20combined%20into,the%20form%20of%20a%20pack, last accessed 29.01.2024

Seneca ESG (2023): *Japan to mandate disclosure of EV battery production emissions*, accessible via: https://senecaesg.com/insights/japan-to-mandate-disclosure-of-ev-battery-production-emissions/, last accessed 29.01.2024

Strategy& (2023): *EU recycling market.* The EU recycling market – a viable and sustainable business, accessible via: https://www.strategyand.pwc.com/de/en/industries/automotive/european-battery-recycling-market-analysis/strategyand-eu-battery-recycling-market-study.pdf, last accessed 29.01.2024

Transport & Environment (T&E) (2021): *Weak climate rules put Europe's battery boom at risk*, accessible via: https://www.transportenvironment.org/wp-content/uploads/2021/08/Battery-brief-1.pdf, last accessed 29.01.2024

Umweltbundesamt (2020): *Effectively tackling the issue of millions of vehicles with unknown whereabouts*. European priority measure: establishing leakage-proof vehicle registration systems, accessible via: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/sciopap_uba_elv_measures_to_combat_illegal_dismantling_2020_06_29.pdf, last accessed 29.01.2024

UNEP (2023): *Electric Vehicle Lithium-ion Batteries in Lower- and Middle-income Countries.* Life Cycle Impacts and Issues, accessible via: https://www.unep.org/resources/report/electric-vehicle-lithium-ion-batteries-lower-and-middle-income-countries, last accessed 29.01.2024

Weng et al. (2023): *Battery passports for promoting electric vehicle resale and repurposing*, accessible via: https://www.sciencedirect.com/science/article/abs/pii/S2542435123001368, in: Joule 7(5): 837-842, accessible via: last accessed 29.01.2024

World Economic Forum (2023): *Digital Battery Passports: An Enabler for Sustainable and Circular Battery Management,* accessible via: https://www3.weforum.org/docs/WEF_Digital_Battery_Passport_2023.pdf, last accessed 29.01.2024

Xu et al. (2022): Future greenhouse gas emissions of automotive lithium-ion battery cell production, accessible via: https://www.sciencedirect.com/science/article/pii/S0921344922004402#refdata001, last accessed 29.01.2024

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

Thank you!

For **additional Battery Pass resources** on the Battery Passport Content Guidance, Battery Passport Technical Guidance and Software Demonstrator, please visit: https://thebatterypass.eu/resources/

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

This project receives funding from the German Federal Ministry for Economic Affairs and Climate Action by resolution of the German Bundestag under grant agreement No 16BZF335.