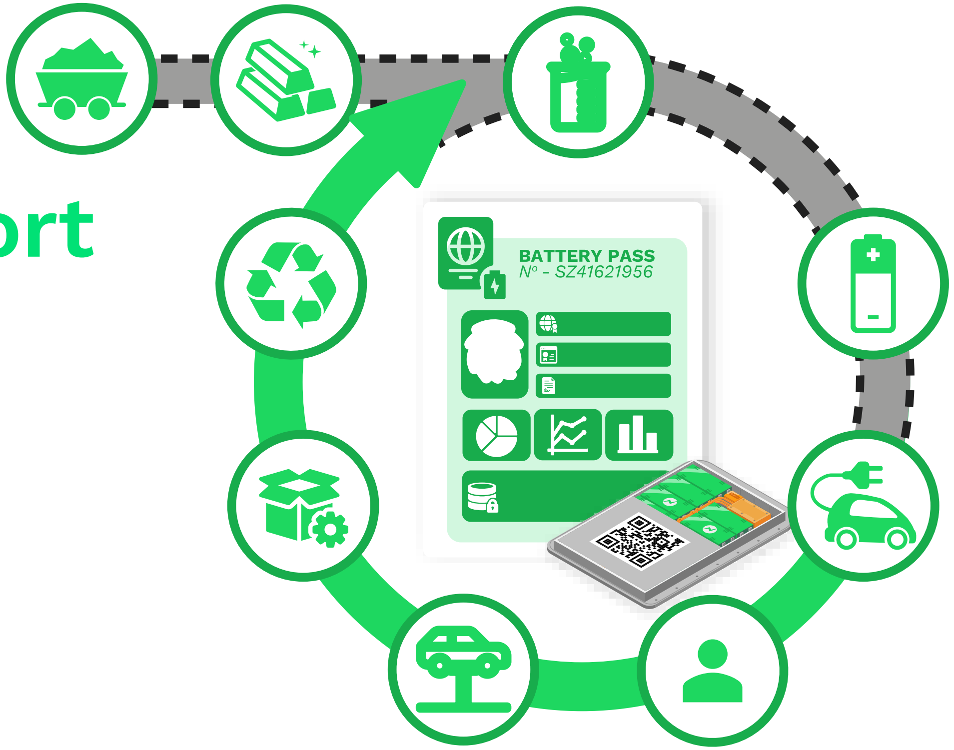
Battery Pass

thebatterypass.eu

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

Unlocking the Value of the EU Battery Passport



Opportunities, challenges, and a roadmap for businesses and policymakers

SYNTHESIS OF RESULTS

November 2024

DISCLAIMER

This document (the “Value Assessment of the Battery Passport – Opportunities, challenges, and a roadmap for businesses and policymakers”) 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 31 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.

Acknowledgements

Authors

Lead:
Sophie Herrmann
Niklas Niemann
Tilmann Vahle
Stephanie Schenk
Andreas Schneider
Anna Braunfels
Achim Teuber
Leonard von Boetticher
Juan Marulanda

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

SYSTEMIQ
Circulor
acatech DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN
TWAICE Battery Analytics Software
VDE RENEWABLES
BASF We create chemistry
Fraunhofer IPK
umicore
FIWARE FOUNDATION
BMW GROUP

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

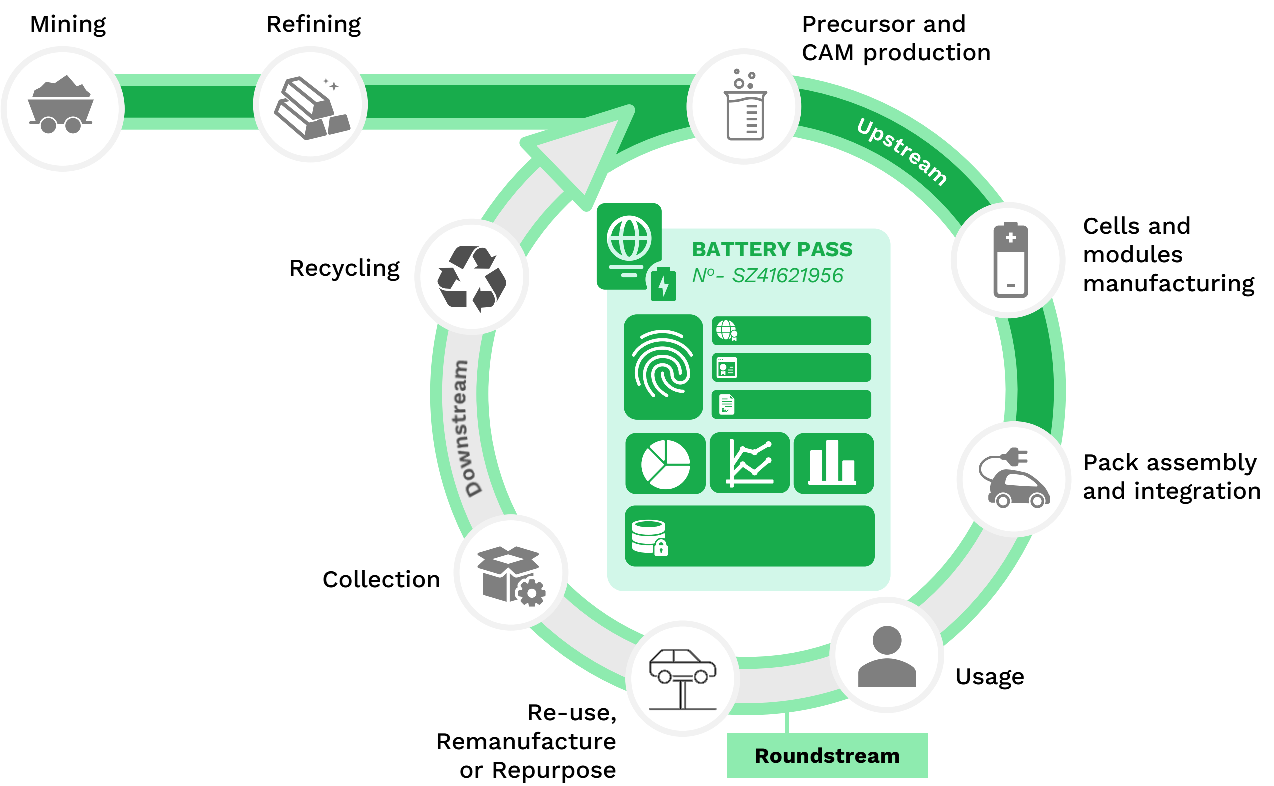
Supported by: Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Executive Summary

1.A Battery passports could be novel tools to support the battery system across its full value chain

Battery passport system-view across the value chain



Battery passports will support to…

- Create an **upstream level playing field** to foster competition through innovation
- Establish ESG profiling as additional **visible differentiators (competitive advantage)**
- Shape **closer ties with suppliers and customers** (e.g. on responsible sourcing)

- Safeguard information needs for **end-of-life process management, development, and optimization** (responsible recycling)
- Make **secondary raw materials more affordable, available, and tuned to needs** through efficiency gains

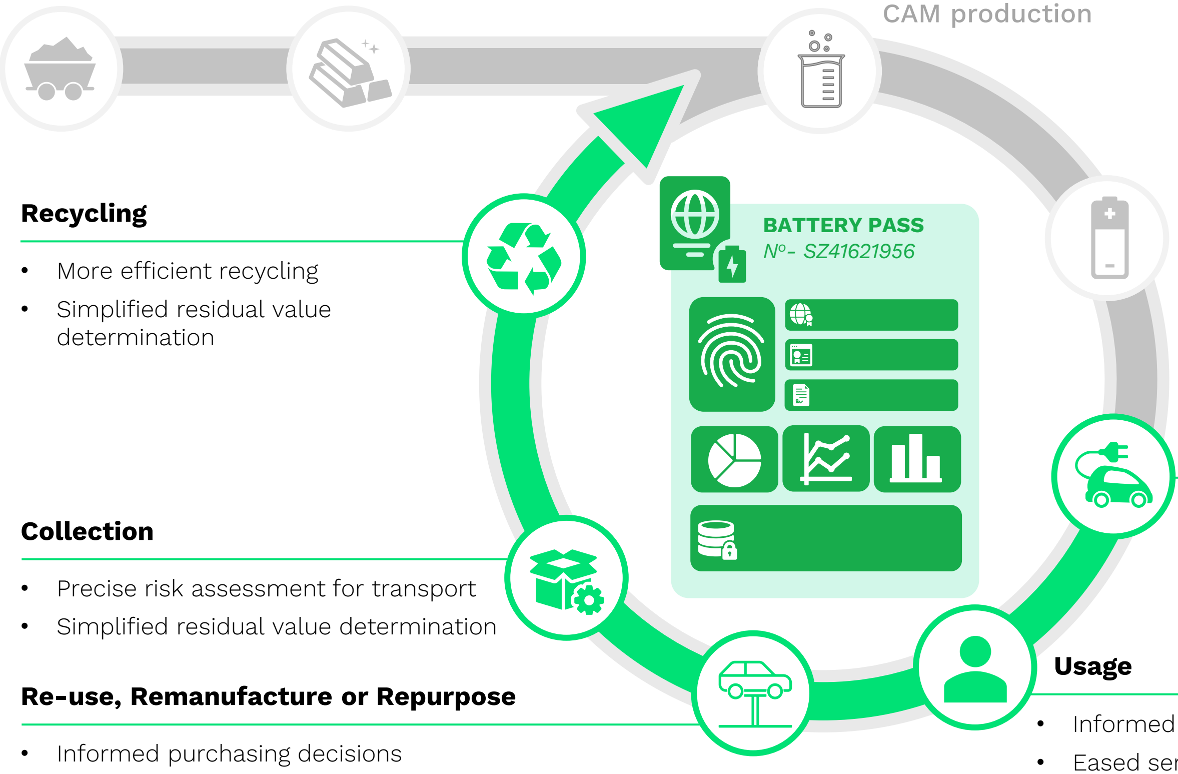
- **Digitalize the value chain** to enable aligned R-strategies, resource efficiency, and circular battery designs
- **Trigger self-reflection processes that create the required awareness** for system changes (responsible transforming)

Domain	Mechanism to unfold system benefit
Upstream	ESG Management Tool → Supply Chain Visibility
Roundstream	Change Management Tool → Circularity
Downstream	Complexity Management Tool → EOL Treatment

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

1.B In its current form, the Battery Regulation stipulates a tool for businesses and consumers, with various use cases creating benefits especially in the downstream

Battery passport use cases identified by the Battery Pass, under current regulation



Recycling

- More efficient recycling
- Simplified residual value determination

Collection

- Precise risk assessment for transport
- Simplified residual value determination

Re-use, Remanufacture or Repurpose

- Informed purchasing decisions
- Eased servicing
- Simplified residual value determination
- Streamlined trade of used and waste batteries through marketplaces

Pack assembly and integration

- Reliable communication of ESG data

Usage

- Informed purchasing decisions
- Eased servicing
- Simplified residual value determination
- Streamlined trade of used and waste batteries through marketplaces

Exemplary quantification of benefits for two use cases

More efficient recycling (annually by 2045)

~10-20%	reduction in operational recycling costs
~4-8 kt	of additional cathode active materials for European recyclers
~30-80 kt	of CO_2 equivalents could be reduced

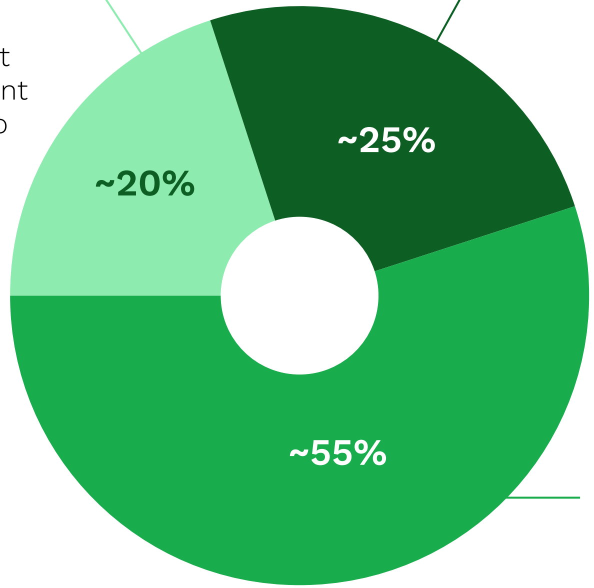
Simplified residual value determination (annually by 2045)

~2-10%	reduction of technical testing costs for independent operators
~60-200 kt	of virgin cathode active materials avoided
~370-1300 kt	of CO_2 equivalents could be reduced

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

2. However, unlocking the full potential of the battery passports faces two challenges of unaddressed implementation efforts and remaining regulatory uncertainties

Battery passport implementation is likely driven by data management tasks and fixed costs, and businesses remain uncertain of requirements



System set-up and provisioning
Incl. battery passport software development and hardware set-up

Operations and management
Incl. software maintenance, access rights management, cloud hosting services, labelling, IT governance and project management

Data management
Incl. collection, integration, and certification

Disclaimer: Values in the chart are based on limited data with high divergence → numbers should only be interpreted directionally

Data management is expected to be the core implementation effort (~55%)

→ Businesses without the right processes and technologies to streamline data management, and sufficient understanding of their specific ability to implement the battery passport, could face sub-optimal implementation

90%+ of required implementation tasks translate to fixed costs with significant tasks such as software development, maintenance, and project management largely independent of volumes of sold batteries

→ Especially SMEs could face difficulties in successful battery passport implementation

Businesses experience significant regulatory uncertainty on implementation requirements. The requirements and effort analysis revealed that outstanding policy clarity on aspects such as "up-to-dateness" of data cause significant uncertainty

→ Without further regulatory specifications, uncertainties will drive associated costs and jeopardize interoperability

→ Businesses without an understanding of policy developments could be caught off guard by requirements

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

3. Business should take three steps to maximise value creation and consider enabling the "efficient reporting" use case by integrating a traceability system to minimise efforts

Businesses should take 3 proactive steps…

1. Assess implementation requirements against business readiness for:
a) Initial battery passport software development and hard-ware set-up
b) Data collection and management
c) Battery passport operations

2. Identify strategic opportunities of the battery passport:
a) Assess which benefits are possible (revenue, cost, funding, resilience, emissions, materiality, social benefit optimisation)
b) Establish a business case and model environmental impact metrics
c) Define an implementation roadmap

3. Select implementation strategies by leveraging and enhancing internal capabilities, sourcing capabilities, and/or joining forces with industry peers. E.g. SMEs may benefit from 3rd-party passport providers, that can spread fixed costs across multiple customers

Integrating traceability systems can yield an additional use case…

- **"Efficient data exchange and reporting based on upstream traceability" is a potential use case** of the battery passport, given its default focus on downstream information transfer
- Merged with upstream traceability systems, battery passports can thus yield **full value chain digitalisation, and address the challenge of opaque, unreliable, and inefficient data exchange with suppliers**
- An interconnecting of systems, and direct instead of reverse system of data reporting, would **establish a mechanism of efficient and dynamic data reporting** by enabling the automated exchange of company-specific data within supply chains
- The system would thereby provide a **digital tool to addresses Article 49 of the Battery Regulation**, defining the establishment and operation of +a system of control and transparency
- Such a system could also promise **significant spill-over benefits, with reporting on other regulation** such as the EU CRMA, U.S. IRA 30D tax credits and UFLPA plus India also experiencing facilitation

Economic operators issuing the passport as well as data providers should attempt to align implementation strategies

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

4. Policymakers should take three steps to minimise uncertainty of battery passports and enable potential use cases with significant impact potential

1. Clarify uncertainties (list non-exhaustive)

1. What is the **legal framework** underlying user obligations to share data during battery use?
2. What does **“up-to-date”** mean?
3. How is lack of **connectivity of batteries** addressed?
4. How should additional **voluntary data attributes** be integrated in the battery passport?
5. Are technical and system developments over time adequately covered by **versioning mechanisms**?
6. What is the **concrete definition of the data points and the framework** of the DPP system?
7. How is **data from downstream 3rd-parties incorporated and responsibility transferred** during EO changes?
8. How are **access rights** defined?

2. Enable significant, “potential” use cases

Integrate battery passports into vehicle de-registration and export procedures

This would increase collection and lead to enough additional cathode active material availability to:

- Fulfil ~5-10% of active material demand for European passenger electric vehicles
- Increase revenue of the EU recycling market by ~5-15%
- Reduce ~2-10% of carbon footprint associated with raw material extraction of active materials for EV batteries demand

Enable data aggregation across different passports

This would enable valuable insights for industry benchmarking, market insights, and informed policy design

3. Ensure general DPP success via 4-steps

1. **Create clarity and support**
Create an easily accessible single source of truth and install required support structures, particularly for SMEs

2. **Ensure sectoral and global interoperability**
In overlapping or adjacent sectors and the global context

3. **Leverage science and industry collaboration**
Involving academia, policy, business and civil society organisations and consortia

4. **Maintain flexibility to adapt to insights**
Adjust the regulatory framework, particularly data requirements and system functionalities as insights evolve

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

5. If action is taken, battery passports could be a digital tool for societal value creation in line with European Green Deal targets, and act as a blueprint for other DPPs

Dimension	Synthesis of value from value chain agent perspective	Green Deal targets
Economy	• **Revenue increases** – Improved ESG differentiation, regional material availability, recycling yields, and value determination for resale revenues • **Cost reductions** – Improvement in reporting, supplier engagement, battery servicing, value determination, transactions, shipping, sampling, dismantling, and material input • **Improved access to capital** – Comparable ESG reporting enables capital allocation to performers • **Level playing field** – Increased transparency on regulatory requirements for market participants • **Risk mitigation and resilience** – Increased critical raw material availability and demand forecasts	Financing and Investment Economic growth decoupled from resource use
Environment	• **Increased circular economy** – Increased incentive for circularity and enablement of life cycle productivity (improved recycling/servicing efficiency and EOL battery collection/allocation[1]) • **Reduced GHG emissions** – Transparent, comparable and systematic carbon footprint information and an improved circular economy • **Less pollution** – Awareness of logistics, collection, and export conditions	Climate Neutrality by 2050 Zero Pollution Ambition Protecting Biodiversity
Society	• **Mitigated social supply chain risk** – Improved transparency on supply chain conditions • **Local employment** – Empowerment of R-strategies and new business opportunities • **Health and safety improvement** – Responsible sourcing and end-of-life treatment	Just Transition

For more information, please visit Chapter 7, page 153 of the Full Document Value Assessment

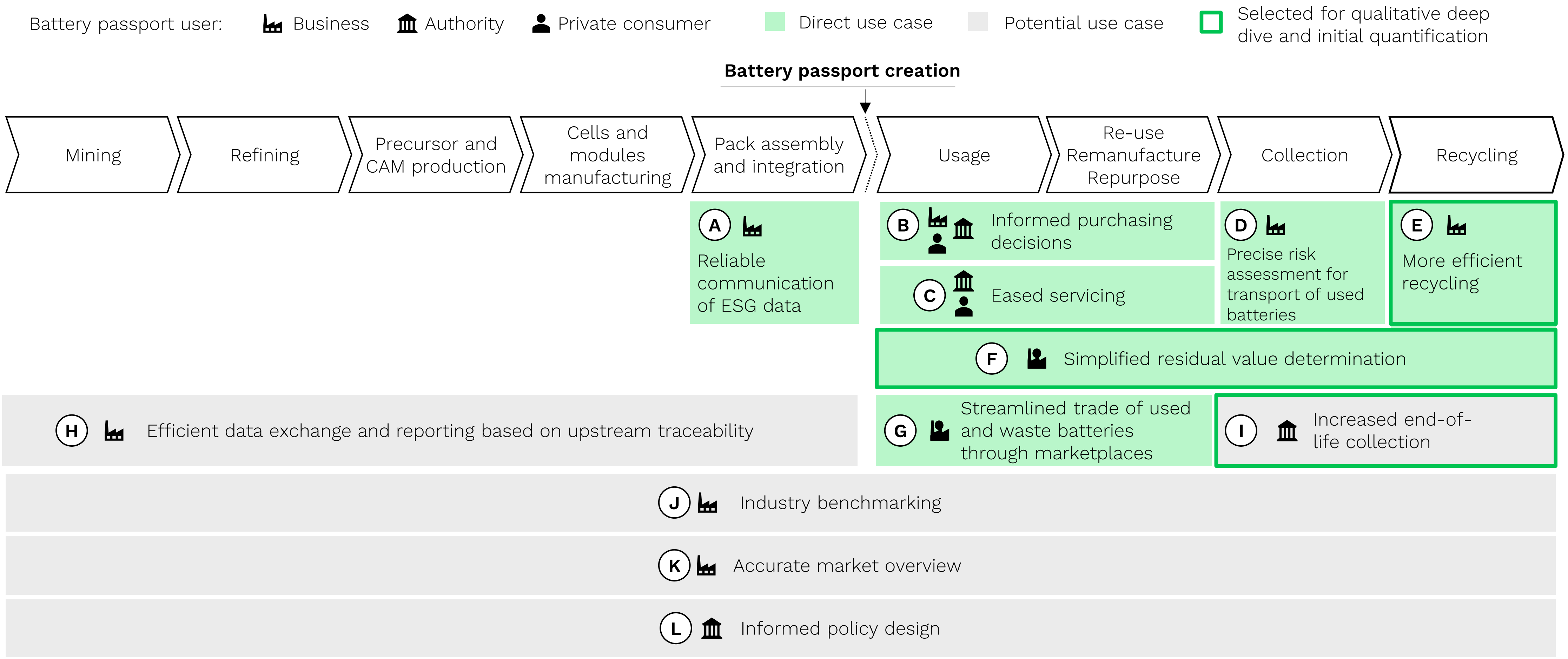
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

The following content section provides selected slides from the chapters of the more detailed full Value Assessment document of the Battery Pass consortium

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

1. Battery passports: A tool for value creation

Overall, twelve use cases of the battery passport were identified along the value chain, of which seven are set to unfold (direct), and 5 require additional enablement (potential)



Note: Use cases are allocated along the value chain step(s) in which the battery passport is used
For more information, please visit Chapter 4, page 43 of the Full Document Value Assessment

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

1.A Direct use cases

Battery passport use cases that result from **mandatory data attributes** required by the EU Battery Regulation in combination with their respective access rights

Brief qualitative-conceptional direct use case description (1/2)

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

Use case	Short description	User	Benefit: Economic	Benefit: Environmental	Benefit: Social	Further info
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.	Business	Middle	Low	Low	Refer to p. 50 of the Full Document Value Assessment
B	**Informed purchasing decisions** Access to reliable and comparable information about the battery (e.g. carbon footprint and durability) facilitates well-informed purchasing decisions.	Business, Authority, Private consumer	Middle	Middle	Low	Refer to p. 51 of the Full Document Value Assessment
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.	Business, Private consumer	Middle	Middle	Low	Refer to p. 52 of the Full Document Value Assessment
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.	Business	Middle	Low	Low	Refer to p. 53 of the Full Document Value Assessment

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

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

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

Use case	Short description	User	Benefit: Economic	Benefit: Environmental	Benefit: Social	Further info
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.	Business	High	Low	Middle	Deep-dive in p. 17-22
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.	Business, Private consumer	High	Middle	No	Deep-dive in p. 17-22
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.	Business, Private consumer	Middle	Low	No	Refer to p. 56 of the Full Document Value Assessment

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

E Deep dive – more efficient recycling: Better information availability in pre-processing steps enables three major improvements

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

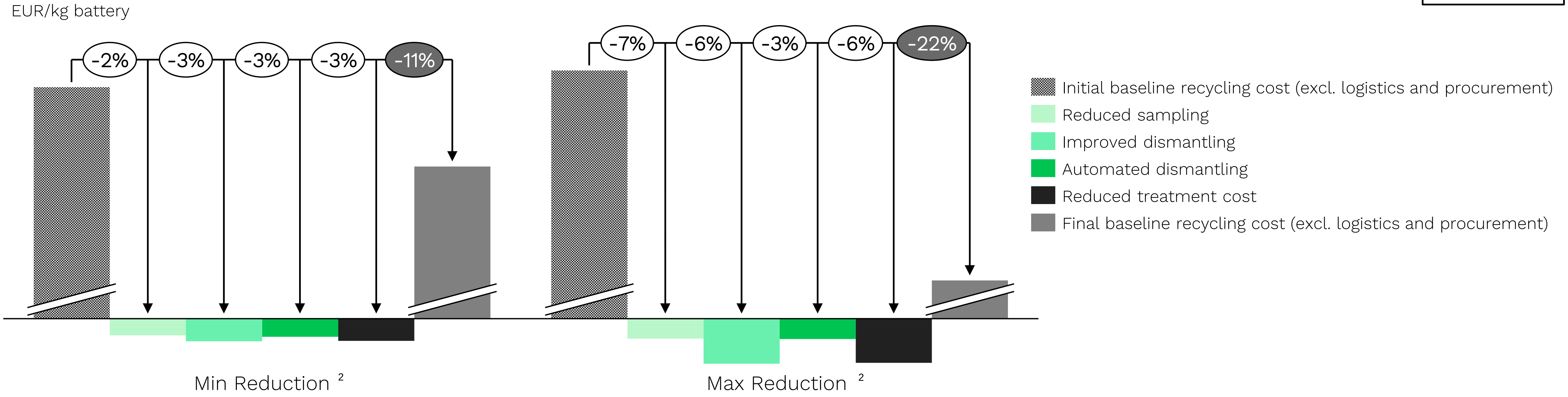
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

E Deep dive – more efficient recycling: 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.

Battery Passport Scenario

Interactive visualisation



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.

For more information, please visit Chapter 4, page 64 of the [Full Document Value Assessment]

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

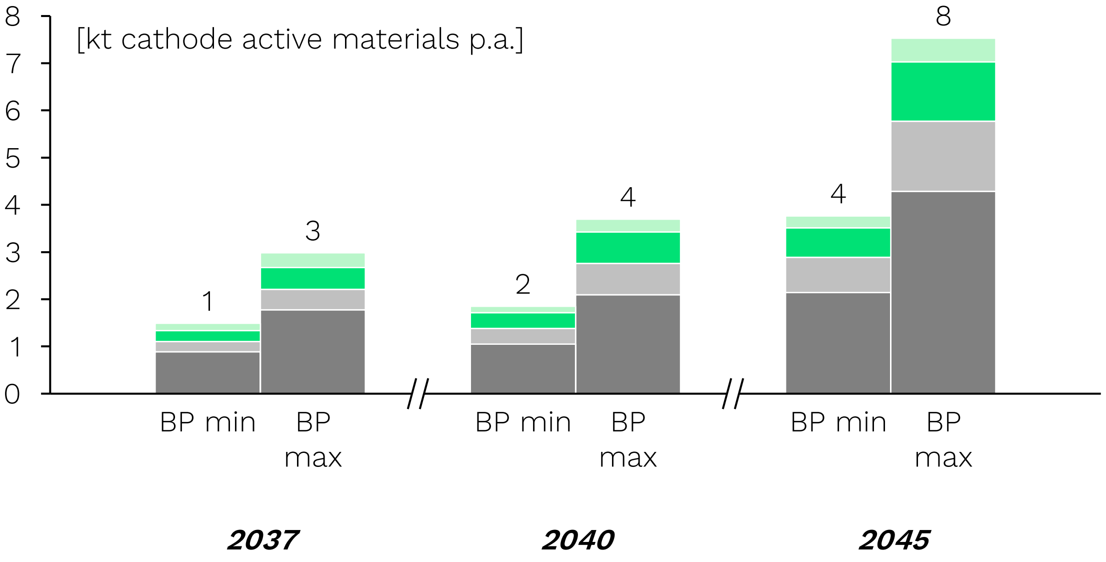
E Deep dive – more efficient recycling: Improving efficiency could lead to additional active materials recovered and associated carbon emissions reduced

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.

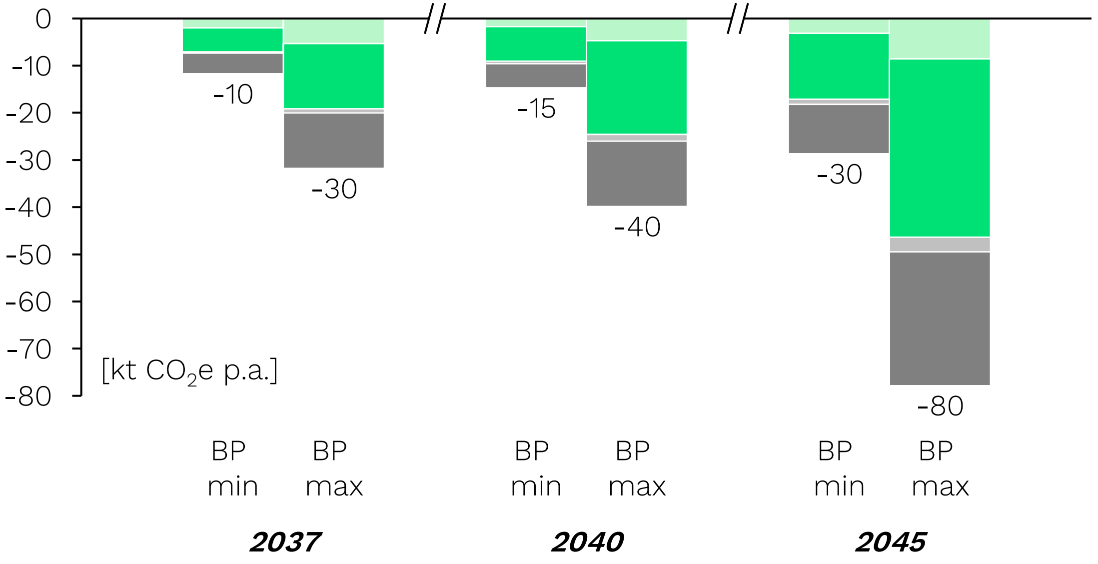


Source: Systemiq analysis (2024), active material intensity based on IEA (2023a) and Leader et al. (2019) see technical annex on slides 130-132 for main assumptions and their sources

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 decarbonisation pathways.

For more information, please visit Chapter 4, page 64 of the Full Document Value Assessment

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

F Deep dive – simplified residual value assessment: Performance and durability data could reduce testing costs and increase number of batteries going into a 2nd-life

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 Battery Management System (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 to assess suitability for reuse
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

For more information, please visit Chapter 4, page 76 of the Full Document Value Assessment

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

F Deep dive – simplified residual value assessment: Up to ~ 2-10% of procurement including technical testing costs could be reduced, depending on sourcing type

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]

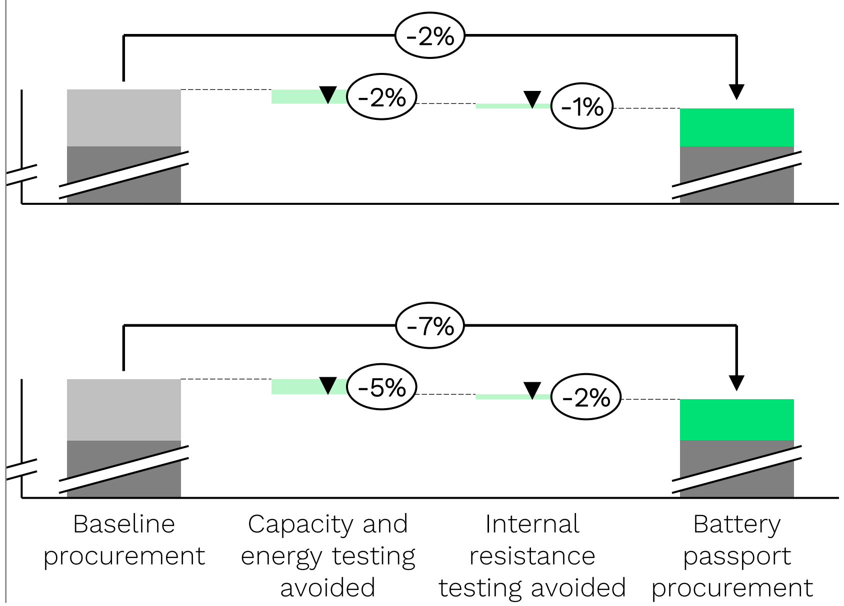
No testing costs, therefore, no improvement potential

Direct sourcing

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

- Share of modules tested[1]: 1%

[EUR/kWh]

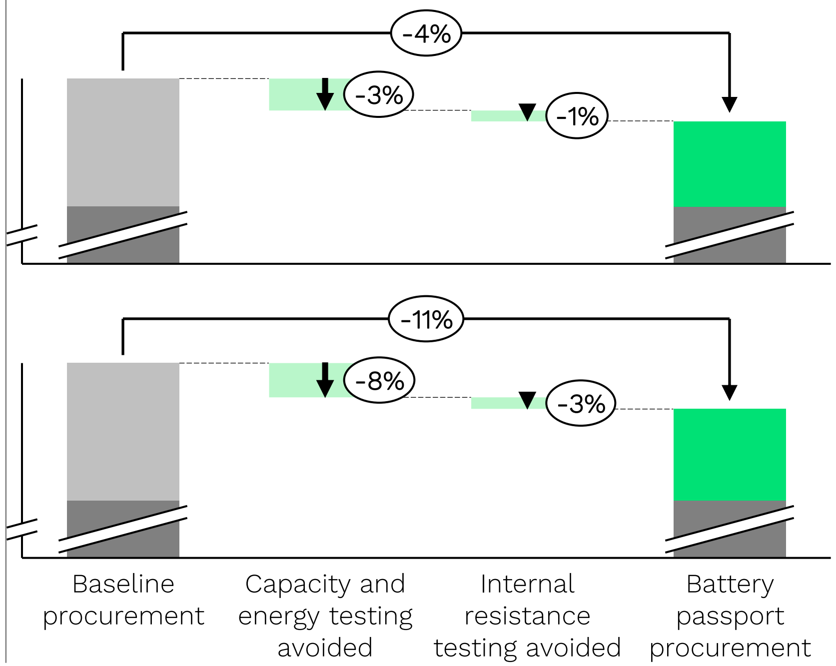


Indirect sourcing

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

- Share of modules tested[1]: 2%

[EUR/kWh]



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)

For more information, please visit Chapter 4, page 76 of the Full Document Value Assessment

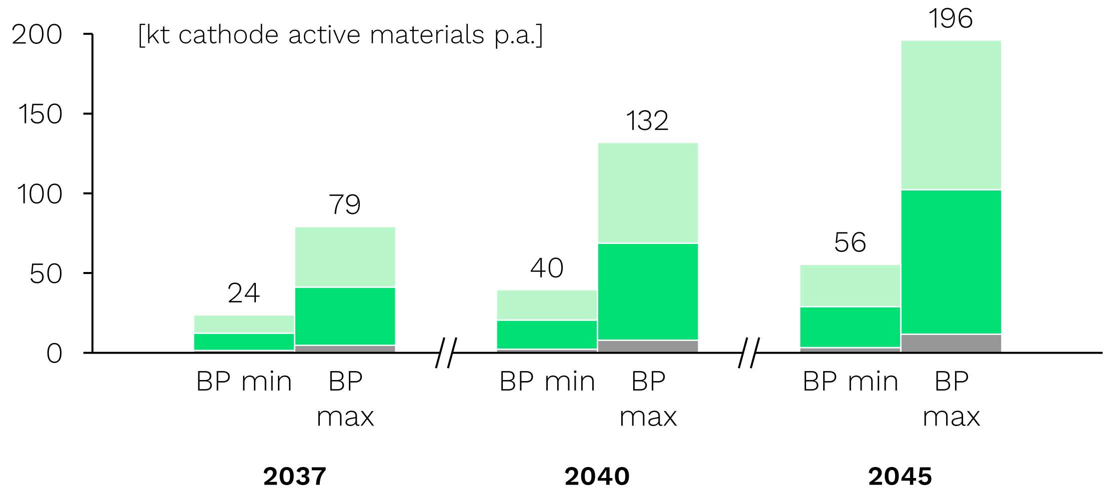
Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

F Deep dive – simplified residual value assessment: The increase in batteries going into a second-life could have significant dematerialisation and decarbonisation impacts

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

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).

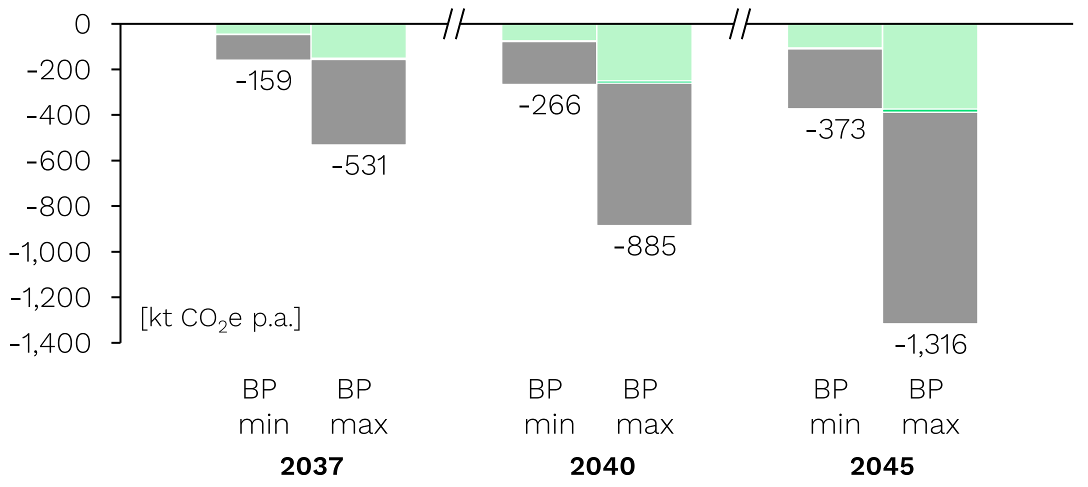


Source: Systemiq analysis (2024), active material intensity based on IEA (2023a) and Leader et al. (2019) see technical annex on slides 133-135 for main assumptions and their sources

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 decarbonisation pathways.

For more information, please visit Chapter 4, page 76 of the Full Document Value Assessment

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

1.B Potential use cases

Battery passport use cases that are **enabled by conditions beyond regulatory requirements** (e.g. traceability, data aggregation, process integration)

Brief qualitative-conceptional potential use case description

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

Use case	Short description	User	Benefit: Economic	Benefit: Environmental	Benefit: Social	Further info
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.	Business	Middle	Low	Low	Refer to p. 89 of the Full Document Value Assessment
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.	Business	High	High	Middle	Deep-dive in p. 25-27
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.	Business	High	Middle	Low	Refer to p. 107 of the Full Document Value Assessment
K	**Accurate market overview** Information aggregated from batteries on the market, including status and expected lifetime, could facilitate market studies and projections, aiding business planning activities along the value chain.	Business	Middle	Low	No	Refer to p. 108 of the Full Document Value Assessment
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.	Authority	Middle	High	Low	Refer to p. 109 of the Full Document Value Assessment

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

I Deep dive – increased EoL collection: The battery passport could 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%.

For more information, please visit Chapter 4, page 89 of the Full Document Value Assessment

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

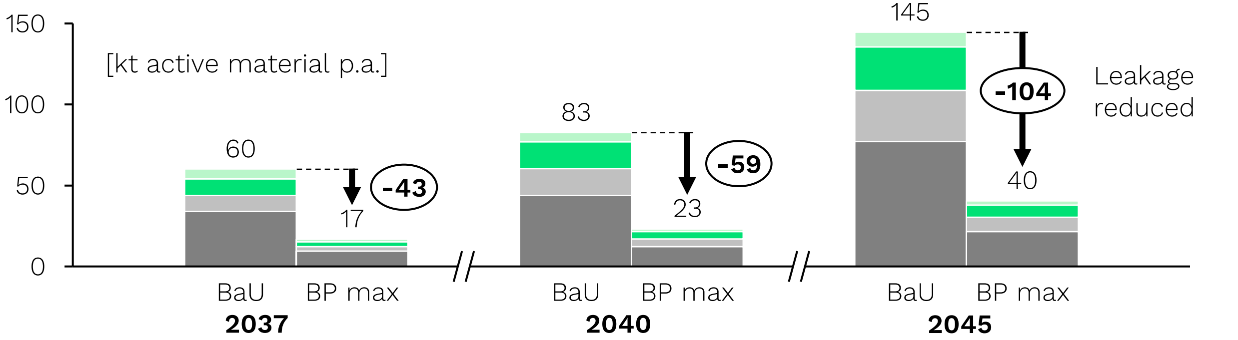
Deep dive – increased EoL collection: Battery leakage reduction could lead to enough secondary active materials available to fulfil ~ 5-20% of passenger EV demand in 2045

Cobalt | Lithium | Manganese | Nickel

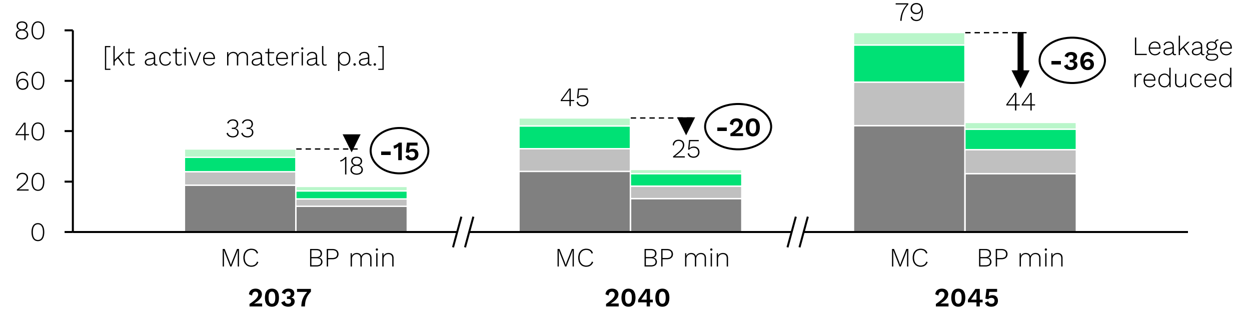
Macro perspective: Materials available on the European market

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)



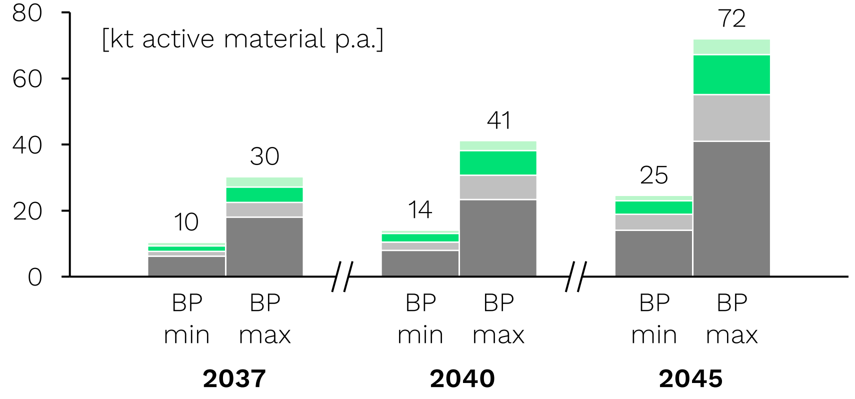
Interactive visualisation

Secondary material additionally available

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 annual material demand** for passenger electric vehicles in Europe.

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

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

For more information, please visit Chapter 4, page 89 of the Full Document Value Assessment

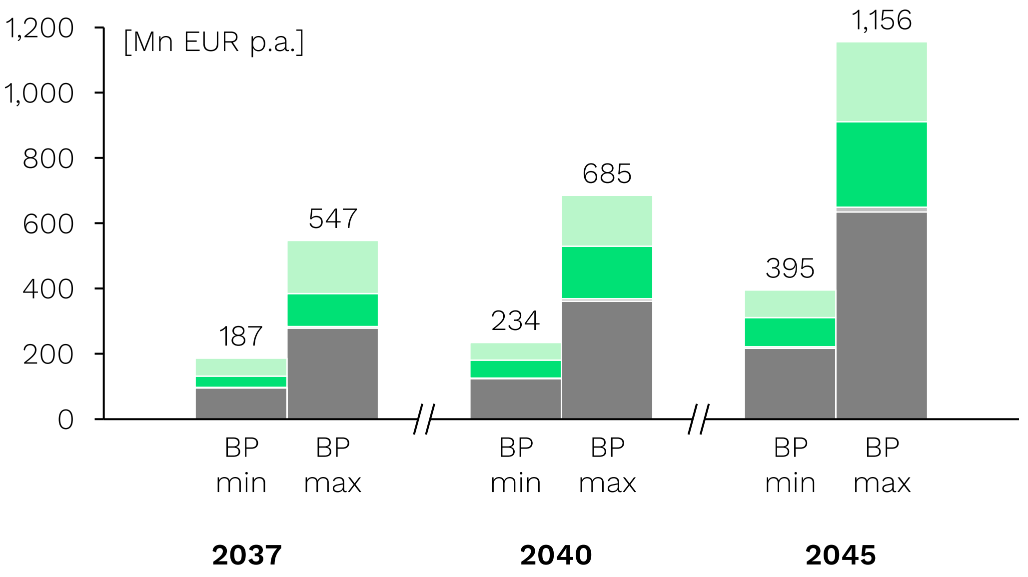
I Deep dive – increased EoL collection: More availability of secondary active material could increase recycling revenue by ~ 5-15% and reduce carbon emission by ~ 2-10%

Macro perspective: Recycling revenue increase and CO2 reduction based on secondary materials additionally available on the European market

Cobalt | Lithium | Manganese | Nickel

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.

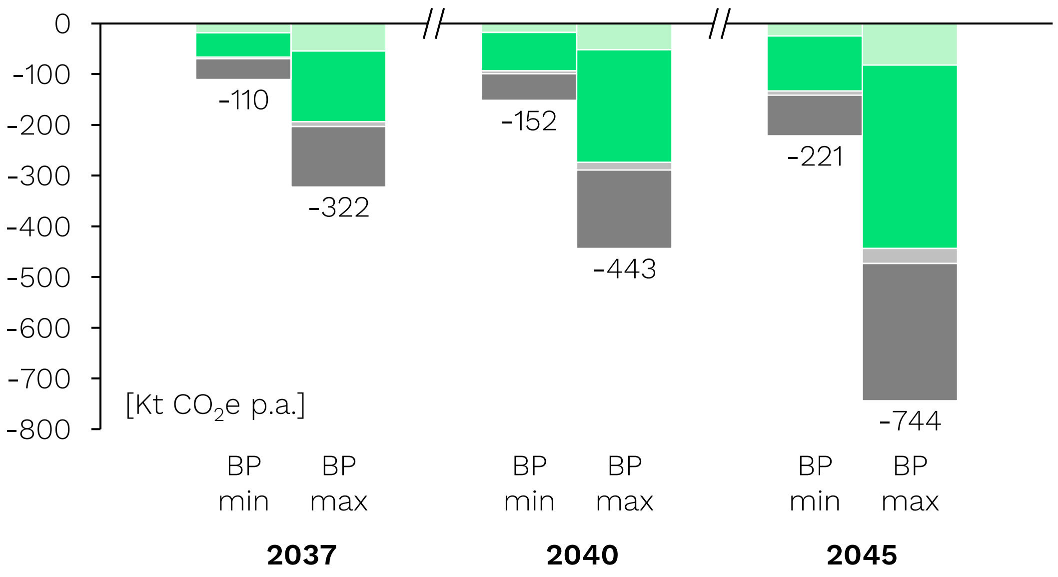


Source: Systemiq analysis (2024), commodity prices based on 5 year-averages from DERA (2023), see technical annex on slides 136-138 for main assumptions and their sources

Reducing battery leakage **could increase the annual 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 annual 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))

For more information, please visit Chapter 4, page 89 of the Full Document Value Assessment

1.C Differences for industrial batteries

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	Key takeaway for industrial batteries specific analysis[1]
(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[1] – Industrial batteries without BMS[1]	The **battery passport supports informed purchasing decisions for industrial batteries with BMS[1]/connectivity**, offering analogous benefits to the general use case. The applicability is reduced for industrial batteries without BMS[1]/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[1]/connectivity.
(D) **Precise risk assessment for transport of used/ waste batteries**	✓ Industrial batteries with BMS[1] – Industrial batteries without BMS[1]	The risk assessment for transportation of used/waste batteries with BMS[1] 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[1] (e.g. Pb-acid, Ni-based) is less complex and does not require dynamic data via the battery passport.

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

1. BMS: Battery Management System

For more information, please visit Chapter 5, page 117 of the Full Document Value Assessment

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	Key takeaway for industrial batteries specific analysis[1]
(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[1]/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 – Partly applicable X Not applicable

1. BMS: Battery Management System
For more information, please visit Chapter 5, page 117 of the Full Document Value Assessment

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	Key takeaway for industrial batteries specific analysis[1]
(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[1] and all static data. No benchmarking of detailed dynamic performance data, is possible for batteries without BMS/connectivity, however.
(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 – Partly applicable X Not applicable

1. BMS: Battery Management System
For more information, please visit Chapter 5, page 117 of the Full Document Value Assessment

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

1.D Differences for Light Means of Transport (LMT) batteries

The separate LMT analysis confirms the applicability of all use cases, highlighting both minor and significant differences

Use case assessment for LMTs

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

Missing connectivity during the use phase is a barrier for unlocking full battery passport potential

- In the low-price segment in particular, connectivity modules required for transmitting dynamic data to the battery passport are often missing.
- **Defining the update frequency and technical options[1] is essential** for LMTs without existing connectivity, to comply with requirements and fully benefit from use cases B, C, D, E, F, G, J, K, and L.

When connectivity is not considered, benefits of use cases A, B, D, G, F, H, J, K, L align with general use cases, with several nuanced examples and specifics

- Use case F: is **mainly** expected for **second-hand use**, with limited application to second-life applications;
- Use case H: battery passports could **facilitate control of EU tariffs on e-bikes** from e.g. China[2];
- Use case L: **safety insights** (e.g. information on accidents) could **support policy decisions on banning e-scooters** from public transport through aggregated battery passport data.

Improving process efficiency with battery passports is a key opportunity for LMT industry

- Given the limited digitalisation among many SME manufacturers, the relatively low battery value, and the complex regulatory landscape, the LMT industry stands to gain significantly from the battery passport use cases C, D, E, F, G, H, I.

Two use cases with more detailed LMT analysis

Use cases C and I have significant differences for LMT batteries which are described in separate one-pagers

Excursus on e-bike theft control

The potential of the battery passport to facilitate e-bike theft control is described in separate one-pager excursus

1) i.e. through connectivity modules or during servicing
2) Custom authorities shall have access to the digital product passport registry for the purposes of carrying out their duties pursuant to Union law (per ESPR, Article 13, paragraph 6).

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

For more information, please visit Chapter 5, page 128 of the Full Document Value Assessment

Eased servicing: The battery passport contributes additional, nuanced improvements for this use case for LMT batteries

Use case analysis specific to LMT batteries

Key takeaways

- **Battery passport information** can **facilitate battery removal and disassembly. Safety concerns** and risks when replacing individual cells should be **thoroughly evaluated**;
- **Voluntary inclusion of repair history** details could **enhance safety**, **facilitate future servicing**, **reduce warranty disputes**;
- **Voluntary inclusion of Right to Repair** directive **information** could **facilitate customer support**.

Key differences for use case "Eased servicing"

§ **Removability and replaceability**	LMT batteries and individual battery cells included in the battery pack, shall be readily removable and replaceable by an independent professional during the lifetime of the product.
§ **Right to Repair Directive**	Applications with LMT batteries are within scope of the Right to Repair directive
Repair events and workshops	LMT batteries face frequent repair / maintenance events which are carried out in a diverse market of independent service providers.

Improvements with battery passport

- The information on removal and disassembly in the battery passport can improve and streamline the currently often manual disassembly process, which needs to handle high variance in design and small production series of batteries.
- Overall, safety risks concerning removal/replacement of individual cells should be thoroughly considered.

- Pertinent information, voluntarily included in the battery passport, can facilitate customer service, e.g.: European repair information form; link to an online matchmaking repair platform.
- Voluntary integration of notifications into battery passport could enable direct communication of new battery repair options to end-consumers.

- Comprehensive and easily accessible data can enable customer support teams to provide more accurate and timely assistance, enhancing customer satisfaction.
- The battery passport can include standardised servicing and safety procedures, ensuring that technicians follow best practices during maintenance events.
- Including voluntary details of battery repair status and history in battery passports could improve future servicing and enhance safety.[1]
- Servicing history information could help manage warranty claims more effectively.

Applications / Market   § Legal Framework

1. Standardising repair definitions is a crucial prerequisite for the handling of repair information.

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

For more information, please visit Chapter 5, page 128 of the Full Document Value Assessment

Increased end-of-life collection: The battery passport contributes additional improvements considering differences of LMT batteries

Use case analysis specific to LMT batteries

Key takeaways

- **Battery passport information** can help to **foster responsible disposal practices and** to **achieve LMT specific collection targets;**
- **Business-owned LMTs** (e.g. shared micromobility services) already have high collection rates, battery passport **impact** is **expected to be minimal**.

Key differences for use case "Increased end-of-life collection"

LMT collection rates	The EU Battery Regulation foresees specific collection rates [1] for LMT batteries: (a) 51% by 31 December 2028; (b) 61% by 31 December 2031 (Article 60(3)).
Privately owned, waste LMT batteries	• Illegal export is not a problem comparable to EV batteries, due to lower value batteries; • Hoarding of LMT batteries that are no longer used is considered a barrier for high collection rates.
Business owned, waste LMT batteries	If businesses own the LMT batteries throughout their lifetime (e.g. shared micromobility providers) collection rates are already high.

Improvements with battery passport

- The inclusion of specific data points like the Information on waste prevention and management of used batteries (Article 74) in the battery passport can boost collection rates by enhancing end-user participation.
- It provides clear information on collection points and take-back programs, making it easier for users to properly dispose of batteries.
- The information in the battery passport can raise awareness about potential effects of hoarding on the environment and economy and foster responsible disposal practices.
- In this case, primarily due to the existing fixed contractual take-back processes, the battery passport is not expected to significantly impact end-of-life collection rates. These established systems already ensure a high level of collection efficiency, reducing the need for additional measures from the battery passport.

Applications / Market | § Legal Framework

[1] Calculation of Collection Rates are defined in Annex XI

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

For more information, please visit Chapter 5, page 128 of the Full Document Value Assessment

In addition, voluntary integrations of the battery passport as a standard framework with other systems could be leveraged to improve e-bike theft protection and control

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

Situation

- **Thefts of high-value e-bikes** are **increasing**
- Every year around 580,000 e-bikes are stolen in Europe[1]
- Low rate solving of cases (< 10%)[2]
- Marketplaces for used e-bikes exist and are expanding
- Increasing number of **voluntary solutions for e-bike theft protection** exist **with no standard framework**, among others:
    - Attached GPS trackers to e-bikes, connected to e-bike and/or third-party software
    - E-bike locks with digital keys
    - Voluntary e-bike pass containing all relevant information and creation of automatic theft report
    - Battery serial number: possibility to check database providing information if serial number has been reported

Potential improvements with battery passport

The battery passport could unlock benefits when used as a **standard framework connected with other systems or services voluntarily**:

- **Integration with existing GPS tracking**
  The battery passport could be linked to GPS trackers and be used by authorities as a monitoring system.
- **Enhanced resale monitoring**
  The battery passport could be linked to resale platforms, to monitor secondary markets for suspicious activity. This could help to identify and intercept stolen goods before they are sold.
- **Consumer alerts**
  The battery passport could highlight stolen batteries by alerting consumers upon scanning the QR code.

1. https://velco.tech/de/schutz-vor-diebstahl-von-elektrofahrraedern-welche-loesungen-gibt-es/
2. Detection rate for German market, source: https://bw.adfc.de/artikel/fahrraddiebstahl

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

For more information, please visit Chapter 5, page 128 of the Full Document Value Assessment

2. Challenges of implementation

The battery passport also presents technical system and capability/resource challenges that could lead to drawbacks if left unmitigated

Challenges and drawbacks[1]

- **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

Mitigation strategies

Technical and battery passport system:

- **Policymakers and authorities**: Define clear regulatory requirements, consult with industry and civil society, support harmonised standards, enforce data security regulations, promote research and development
- **Businesses**: Prepare early with fallback plans, engage in standardisation, invest in interoperable technologies, and implement strong data governance for security.

Capabilities and resources:

- **Policymakers and authorities**: Provide financial support or incentives, define clear regulatory requirements, harmonise with international regulations, and raise awareness among stakeholders
- **Businesses**: Align internally, invest in training, collaborate through industry networks, form strategic technology partnerships, and adjust contracts with customers and supply chain partners.

While unmitigated challenges may decrease the passport's overall value, the **benefits** derived from above explained use cases are **expected to outweigh the drawbacks**

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

1. Only applicable for businesses

For more information, please visit Chapter 5, page 137 of the Full Document Value Assessment

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	End-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

For more information, please visit Chapter 5, page 137 of the Full Document Value Assessment

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 — Effort required for the implementation — Negative impacts of the implementation — Positive impacts of the implementation

	Drawbacks	vs	Benefits
Economic	**Investment needed** in the passport software/hardware, data management, and the passport operations	<	**Cost decrease** enabled by more efficient operations
Economic	**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
Environmental	**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
Social	**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
Social	**Job displacement** of lower-skilled jobs that become automated or unnecessary	<	**Job creation** through digital transformation leading to generation of higher skilled jobs

Deep-dive in next slides

For more information, please visit Chapter 5, page 137 of the Full Document Value Assessment

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

The battery passport implementation requires three general effort steps that include several underlying tasks

Step 1

System set-up and provisioning

- Battery passport software development and licenses
- Hardware set-up for battery passport (company-owned)

Step 2

Data collection, integration, certification

- Data collection (external upstream, static vs dynamic)
- Data integration (extraction, transformation, loading)
- System and data certification

Step 3

Operation and management

- Software maintenance, service fees (SaaS[1]) and updates
- Access rights management
- Cloud hosting services
- Labelling
- IT governance (membership fees, tech selection)
- Project management, third-party consulting and legal

1. Software as a Service

Source: Task split based on CIRPASS study of DPP costs (https://cirpassproject.eu/wp-content/uploads/2024/02/CIRPASS-A-study-on-DPP-costs-and-benefits-for-SMEs-v1.0-1.pdf)

For more information, please visit Chapter 6, page 143 of the Full Document Value Assessment

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

1 System set-up and provisioning task explanations

Effort categories and tasks		Task explanation: Effort to...
System set-up and provisioning	Battery passport software development and licenses	**Develop the battery passport software** (distributed DPP system services) and/or purchase software licenses - Entails salaries (developers, designers, testers, etc.), licenses for development tools, costs for software libraries or frameworks, and training - Developing and establishing the internal system architecture[1], as well as the front-end[2] and back-end software for the battery passport - Developing (or integrating) and establishing the relevant interfaces, APIs and translator services (internal, to ECC central services, to third-party backup services) - Ensuring proper mechanisms for downstream data inclusion and hand-overs when transfers of responsibility occur (e.g. with the remanufacture of batteries)
	Hardware set-up for battery passport solution	- **Establish additional hardware the company requires to enable the battery passport** - This includes servers, routers, switches, firewalls and storage systems

2 Data collection, integration, certification effort task explanations

Effort categories and tasks		Task explanation: Effort to...
Data collection	External upstream	- **Collect upstream data for new batteries.** - Established once for each battery passport, but data requires regular updates to keep upstream data of future battery passports up-to-date - Utilising traceability software could help for proficient levels of supply chain transparency and potential cost savings if multiple battery models are involved
	Internal static	**Collect internal static data from different departments for new battery models.** Also included is **additional hardware, especially test stands that may be required to obtain internal static data.**
	Internal dynamic	- **Regularly collect performance data from each battery during its use-phase** - Given high volumes/frequency of data collection, this is likely automated and entails mostly integration efforts (assessed separately in next category) - Additional development efforts for the battery management system to calculate and accommodate all dynamic data requested in the battery passport
Data integration		- **Technically extract, load and transform data** as well as complete manual tasks such as verification - Integrations need to be established via APIs[1] to connect different data sources such as the battery management, PLM[1], ERP[1], SCM[1], and traceability systems with the battery passport back-end
Verification and reporting		**Auditing data and systems regarding the declaration of conformity and reporting on testing**

1. API (Application Programming Interface), PLM (Product Lifecycle Management), ERP (Enterprise Resource Planning)

For more information, please visit Chapter 6, page 143 of the Full Document Value Assessment

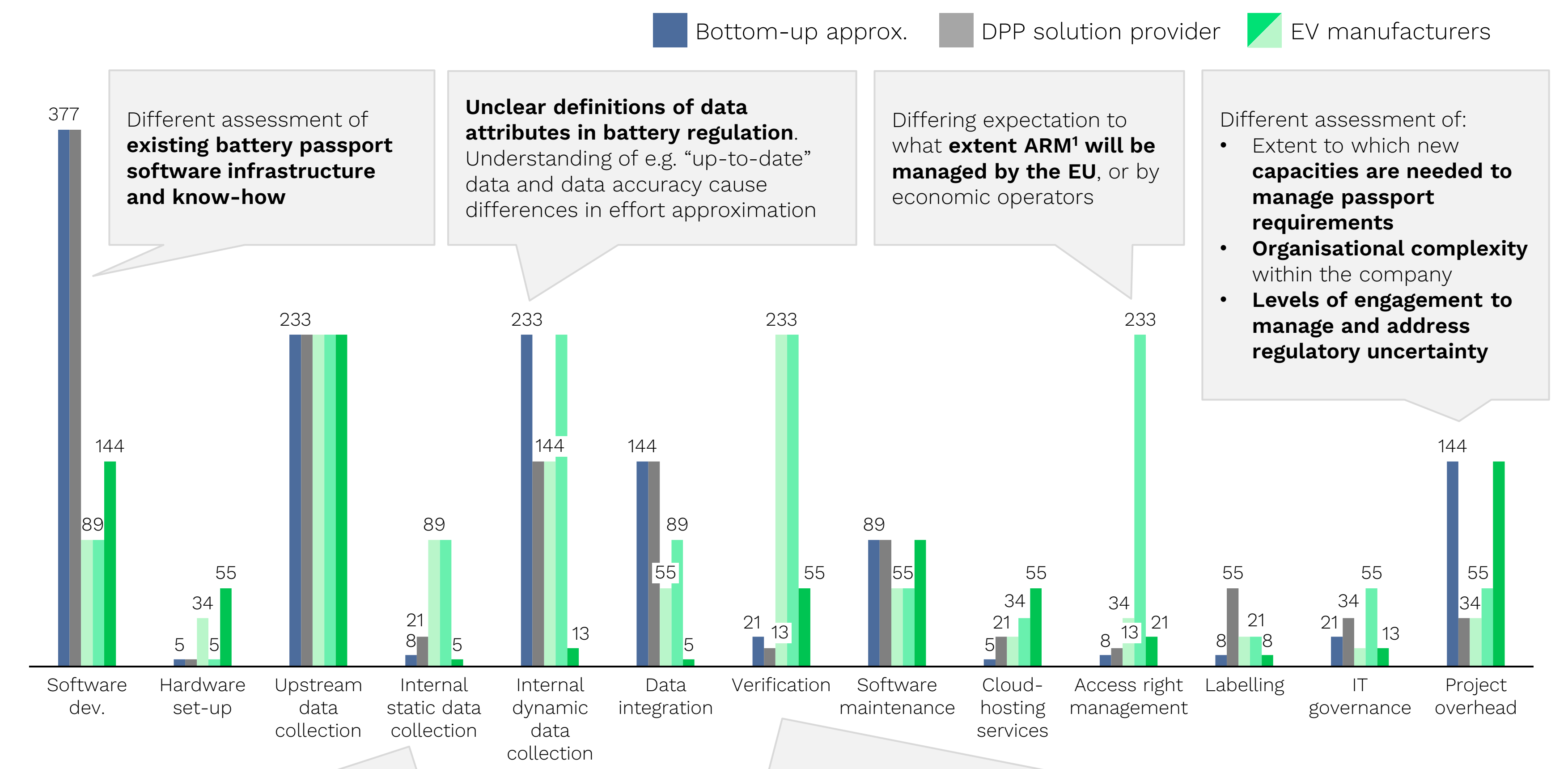
3 Battery passport operation and management effort task explanations

Effort categories and tasks		Task explanation: Effort to...
Battery passport operation	Cloud hosting services	**Provide and maintain access to virtual servers for storing, managing and processing passport data on external cloud infrastructure**. This includes efforts for data migration, archiving and independent providers to maintain back-ups
	Software maintenance, service fees and updates	- **Apply corrective, adaptive, perfective, and preventive maintenance and updates** on company-owned software - Recurring fees for third-party software integrations (battery passport components can be bought on a functional level)
	Access rights management	- **Manage software access to restricted battery passport data, based on stakeholder access groups** being specified in coming EC delegated acts - Includes the correct handling of credentials (e.g. Verifiable Credentials) and the management of all relevant access polices[1]
Labelling	Product identifiers and labelling software/hardware	Obtain all **relevant technology and licences to create QR codes and apply them to batteries** in the production line. Provide dealers and online marketplace providers with a digital copy of the data carrier or unique product identifier, to allow accessibility to potential customers where they cannot physically access the product.
IT governance	Membership and onboarding fees	**Finance memberships to data spaces** such as Catena-X, Gaia-X Digital Clearing Houses
	Changes in selected technology and software changes	**Select, monitor and maintain changes to third-party tools** such as e.g. a traceability system and the overall BP system architecture
Project overhead	Project management	**Manage the battery passport implementation**, including personnel training
	Third-party consulting and legal costs	**Apply third-party services for business, technical, and legal matters** related to the battery passport

Battery passport implementation effort estimates vary significantly – unclear regulation was flagged as a key source of uncertainty

Battery Passport implementation efforts (Fibonacci scores) as approx. by EV OEMs

Deviation of efforts related to…



Different assessment of **required test hardware for static aging**

Expectation that **initial system set-up and high continuous auditing efforts to warrant completeness and correctness** of data will exist, vs the expectation that while initial set-up of auditing system is significant across all reporting systems, they are limited over time and for a scope restricted to passport attributes

Highlights

Interpretation of effort varies significantly and yields only directional insights on effort due to:

1. Lack of clarity on how much effort the passport will entail

- In particular, **uncertainty in regulation was repeatedly flagged as a cause of uncertainty** in effort, mostly in dynamic data integration, certification, ARM[1], and project overhead
- Regulators should aim to clarify/ specify the battery regulation to reduce uncertainty for businesses

2. Differing circumstances across companies (size, resources, etc.)

- This is especially the case for the passport software development and project overhead

3. Human error or bias in the estimation

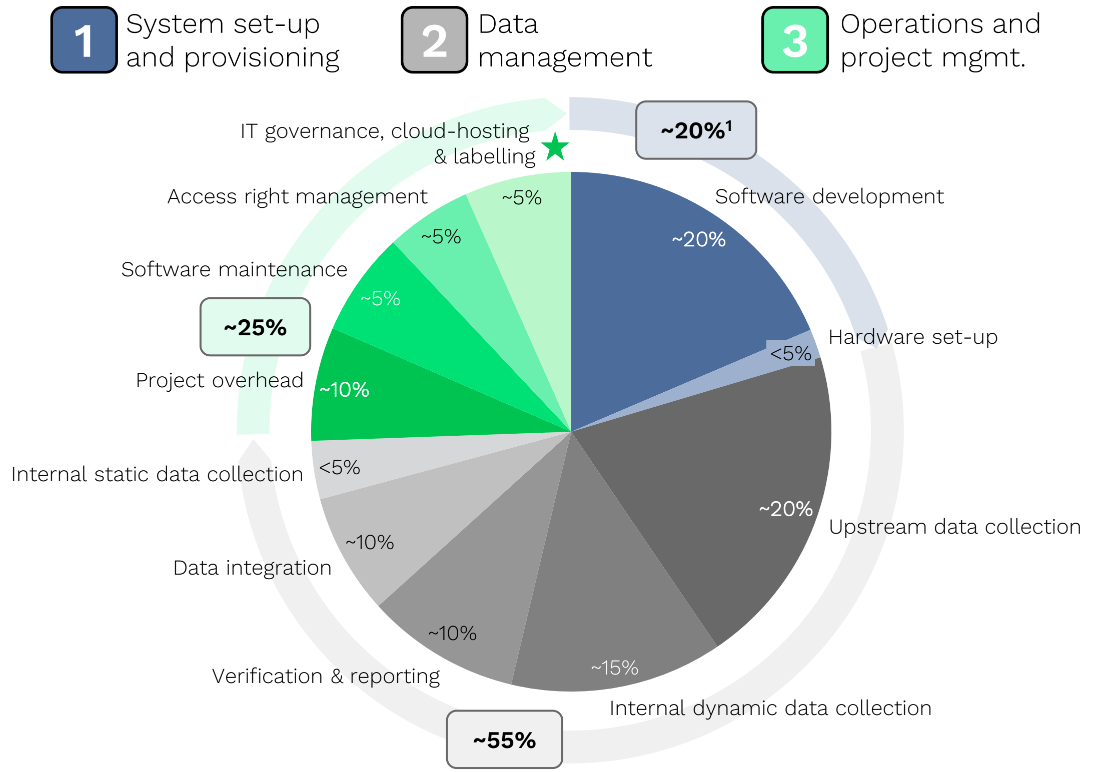
1. Access Rights Management
Source: Systemiq analysis (2024) based on survey, internal approximation, and expert interviews

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

For more information, please visit Chapter 6, page 143 of the Full Document Value Assessment

Approximate battery passport implementation effort for EV economic operators is caused mostly by data management, while most tasks classify as fixed costs

Averaged relative efforts of implementation categories and tasks[1]



★ Variable cost, increasing with number of battery passports (others fixed)

Disclaimer: Values in the chart are highly uncertain and based on limited data, with coefficients of variation[2] of up to 130% → numbers should only be interpreted directionally

Highlights

Data management is the most significant category (~55%) of effort to implement the battery passport. In the words of one EV manufacturer: "The battery passport is primarily a data management task"

→ Standards, processes, and technologies to streamline data management are key impact areas to facilitate net value of the battery passport

Software development and upstream data collection are the largest tasks (~20%) of the battery passport implementation, followed by internal dynamic data collection (15%)

→ Software and data knowledge is a key lever that impacts passport implementation effort

90%+ of efforts translate to fixed costs with significant tasks such as software development, maintenance, and project management being independent of the volume of sold batteries and only the last category identified as mostly variable

→ Third-party service providers that can spread fixed costs across multiple clients may reduce total implementation effort

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

1. Results rounded to the nearest 5%. If between 0-4%, noted as "<5%" – this causes totals, e.g. of >100%
2. Coefficient of variation = standard deviation/mean (measures the variability of a dataset)

Source: Systemiq analysis (2024) based on survey, internal approximation, and expert interviews,

For more information, please visit Chapter 6 page 143 of the Full Document Value Assessment

LMT or industrial battery economic operators, and SMEs in general, could face a higher relative effort to implement the battery passport, requiring the right strategy and support

Differences for LMT and industrial batteries

Multiple SMEs especially in LMT vehicle market
- Fragmented market; higher share of SMEs in LMT vehicles market
- Low market power; reliance on single suppliers
- Lower market volume for industrial batteries compared to the electric vehicle market

Lower battery value to cover expenses
- Lower unit price → higher relative effort for passport implementation, especially for LMTs
- Lower battery value with less precious materials → less incentive for recycling investments

Differing effort for data collection
- Several attributes do not apply or only apply to industrial/LMT batteries (e.g. capacity threshold for exhaustion or initial self-discharging rate)
- Connectivity: batteries w/o BMS[1] or connectivity module require added effort to collect performance data (e.g. remaining capacity) and fulfill regulation
- LMT batteries face different handling operations, e.g. more frequent repair/maintenance events

Differences for SMEs

Lower economies of scale
- Estimated 90%+ of effort will be fixed costs → spread across fewer batteries sold, increasing effort per unit of production
- Smaller scale also entails lower market power and potentially higher variable costs (e.g. lower bulk order benefits)

Lower economies of scope
- Lower likelihood for SMEs to benefit from using existing technological, financial, and human resources to implement the battery passport
- Required investments potentially higher for SMEs relative to larger enterprises

Easier change management
- Lower internal complexity could reduce management costs of the passport implementation

Implications

Battery passport as a service
Likely beneficial for SMEs to work with DPP providers that:
- Spreads fixed costs across multiple clients
- Possess existing solutions and resources to supply the battery passport

Providers could be dedicated DPP-aaS companies or battery manufacturers providing passport with batteries sold

Industry collaboration
Consortia or alliance with other companies to share costs and resources for passport implementation

Government support
Potentially high relative costs to SMEs, especially for LMT and industrial batteries, may necessitate EU support

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

1. BMS: Battery Management System

For more information, please visit Chapter 6, page 143 of the Full Document Value Assessment

3. Business actions to safeguard competitiveness

A need to act: Businesses should proactively prepare in three steps to maximise value creation of the battery passport implementation

1. Establish operational readiness for implementation

Assess requirements versus corresponding business readiness in three effort categories:

- **1** Initial **battery passport development** (details)
- **2** **Data management** (details)
- **3** Battery **passport operations** (details)

Data management: **Data providers (upstream)**

All three: **Battery passport providers**

Requirements should be monitored, as these will still evolve (see "unanswered questions")

2. Identify strategic opportunities of the battery passport

a) **Internally assess which battery passport benefits are possible** (e.g. dismantling cost reductions in recycling):

- **Revenue** increases, **cost** reductions, access to **capital**, or **supply chain resilience** (details)
- GHG **emission** reductions, **circular economy** improvements, or **pollution** mitigation (details)
- Mitigated **social supply chain risks**, **health and safety** concerns, or increased local **employment** (details)

b) **Establish a business case and/or model environmental and social impact** (e.g. quantification of dismantling cost savings vs required investments)

c) **Define an implementation roadmap to address identified opportunities** (e.g. types and timelines of required investments for automated dismantling)

3. Select implementation strategies

Use and enhance internal capabilities
Communicate requirements and provide training and resources to internal departments / teams

Source capabilities
Understand solution provider landscape and available services, and strategically partner

Join forces
Collaborate with industry peers and consortia to share knowledge and/or investments

For first-mover benefits: Join demonstrators and pilots to gain practical experience and knowledge ahead of a mandate. First OEMs are starting to issue DPPs already today - when non-compliant solutions are not an issue, but an opportunity for learning.

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

There are four strategic questions businesses should address in preparation for a battery passport implementation

1. Wait or act?
Analyse cost of inaction (e.g. potential loss of customer contracts or even market access, excess costs due to late implementation) compared to cost of action (e.g. redundant implementation; uncertain requirements raising development costs; immature supplier data).

---

2. Compliance vs business value?
Consider if battery passports are a compliance necessity (limited value, lower cost) or a strategic opportunity. While minimal solutions may suffice for tactical compliance (e.g., SoH, durability), advanced solutions offering detailed data (e.g., due diligence, circularity) can enhance value through improved sourcing, transparency, and partnerships, providing a competitive edge.

---

3. Make or buy?
DPP service providers and consortia, such as Catena-X, have started offering solutions for battery passports. Assess your organisation's capacities, capabilities, economic situation and strategic position: you may consider developing value-creating solutions in-house (for corporates with scale) or buy standard solutions outsourcing the fulfilment of your legal requirements (for SMEs with limited scale).

---

4. Existing infrastructure or green-field?
You might still have legacy infrastructure or have already started building a new one. Consider how this affects your make-or-buy decision and your cost position. Starting from scratch can seem daunting and costly but keeping legacy infrastructure in place might come with further efforts.

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

Businesses facing the implementation of other DPPs can use multiple battery passport elements as a blueprint

Transferable aspects of the battery passport

System set-up and provisioning of the DPP hard- and software	Data collection, integration, and certification	Passport operations
• **Back-end, interoperable system architecture** is largely reuseable by other DPPs • **Front-end software** is likely to be adapted to different data requirements, but fundamental functionalities can be reused • **Hardware set-up requirements** will be the same, including servers, routers, switches, firewalls and storage systems	• **Upstream data collection** will require similar processes of supplier communication and organisational setup • Some **upstream data attributes** will be similar, such as carbon footprint and recycled content, with analogous standards • **Internal data collection as well as data integration** will be simpler for most other DPPs, as dynamic performance data will often not be relevant[1] • **Auditing procedures** are likely directly transferable to other DPPs	• **Cloud hosting services, software maintenance, IT governance and access rights management in other DPPs** will use the same procedures as the battery passport • **Labelling requirements** could differ between DPPs, given different product characteristics • **Project management procedures** are streamlined via available experience of requirements and how to address them (while this is internal information of companies, experienced service providers may provide relevant insights)

General implications

- A wider and lower cost **offering of developed technical DPP solutions** that can be integrated
- Detailed **documentation available on battery passport system set-up**, partially valid for other DPPs
- A more **experienced set of service providers** that can be contracted, and personnel that can be hired

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

1. Dynamic data attributes could be required in the future for vehicles (not currently planned in DVP) and electronics

4. Policymaker actions to maximise value and minimise uncertainty

Policymakers should resolve unanswered questions to avoid uncertainty for businesses

Unanswered questions	Required measures by policy-makers	Relevance
1 What is the **legal framework** underlying user obligations to share data during the battery use phase with EOs[1]?	Analyse and address required legal frameworks to enable dynamic data sharing while protecting user privacy rights	**Potential exploitation of user data** and associated mistrust of the public
2 What does **“up-to-date”** mean for dynamic data attributes?	Provide information on how to interpret requirement of “up-to-date” dynamic data	**Uncertainty of implementation effort** and potential cost advantage to companies least ambitious on battery passport
3 How is a lack of **connectivity of batteries** (various reasons of missing internet connection) addressed?	Ensure exception management in data analytics due to data gaps from lack of connectivity	**Realistic interpretation of data** and expectation management for implementation
4 How should **additional voluntary data attributes** be integrated in the battery passport?	Specify guideline on additional voluntary data reporting	Uncertainty of utilisation of battery passport as a **business tool, including new business models**
5 Are technical and system developments over time adequately covered by **versioning mechanisms**?	Establish adequate versioning mechanisms and implementation rules in battery passport system design	Necessary to **avoid compatibility problems** over time in operations across battery passport systems
6 What is the **concrete definition of the data points** and the **framework** of the DPP system?	Clarify the definition and framework through close work in standardisation	Enables **conformity with battery regulation** and ensures **applicability of legal requirements**
7 How is **data from downstream third-parties incorporated and the transfer of responsibility managed**?	Decide on process for downstream third-party data inclusion and harmonise the mechanism for transfer of responsibility	It is necessary to **establish responsibilities and roles for up-to-date use of phase data and battery passports**
8 How are **access rights defined**?	Specify the access rights definition in a delegated act as soon as possible	Required to **prevent access conflicts and provide clarity on implementation effort**

→ **Multiple questions need to be addressed by the European Commission; in the meantime, businesses should proactively address known system requirements to avoid an unprepared implementation by 2027**

1. Economic operators
2. Statistical compensation measures for missing data likely required

For more information, please visit Chapter 7, page 161 of the Full Document Value Assessment

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

Four potential use cases could be enabled if policymakers address conditions which would go beyond current regulatory requirements

Conditions required beyond regulatory requirements...	...to enable potential use cases
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** See slide 25-27 for details
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** See slide 23 for details

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

Policymakers should take four general steps to ensure a success implementation of the battery passport, as well as other DPPs

Core challenges accompany DPP deployment

Implementation
- DPPs entail significant **implementation effort** for businesses, and thus represent a bureaucratic burden
- The **specifics of technical implementation** are unclear and unharmonised

Awareness
- Some businesses are unaware of upcoming **DPP requirements**
- **The value of DPPs is unclear** to some stakeholders across the sector and value chain

Regulation
- **Interoperability** with other countries, DPPs, and regulations is not warranted
- **Regulation does not adapt** as insights on most sensible requirements evolve

Policymakers should take 4 steps to ensure system success across DPPs

1 Create clarity and support
Pre-empt uncertainty well ahead of entry into force by creating an easily accessible single source of truth and installing required support structures, particularly for SMEs[1]

2 Ensure sectoral and global interoperability
Safeguard that various DPPs make sense together, particularly in overlapping or adjacent sectors, and continuously nurture their fit into a global context

3 Leverage science and industry collaboration
Establish sources/consortia for transparent and qualified recommendations, involving academia, policy, business and civil society organisations disseminating through publications and events

4 Maintain flexibility to adapt to insights
Ensure flexibility to adjust the regulatory framework, particularly data requirements and functionalities of the system as insights evolve

1. Educational programs or measures to inform the general public could be valuable to provide understanding

For more information, please visit Chapter 7, page 161 of the Full Document Value Assessment

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

5. Unlocking societal value across the value chain

Back to overview

Total impact: The battery passport could create societal value that strongly maps to European Green Deal targets

Dimension	Synthesis of value from value chain agent perspective
Economy	• **Revenue increases** – Improved ESG differentiation, regional material availability, recycling yields, and value determination for resale revenues • **Cost reductions** – Improvement in reporting, supplier engagement, battery servicing, value determination, transactions, shipping, sampling, dismantling, and material input • **Improved access to capital** – Comparable ESG reporting enables capital allocation to performers • **Level playing field** – Increased transparency on regulatory requirements for market participants • **Risk mitigation and resilience** – Increased critical raw material availability and demand forecasts
Environment	• **Increased circular economy** – Increased incentive for circularity and enablement of life cycle productivity (improved recycling/servicing efficiency and EOL battery collection/allocation[1]) • **Reduced GHG emissions** – Transparent, comparable and systematic carbon footprint information and an improved circular economy • **Less pollution** – Awareness on logistics, collection, and export conditions
Society	• **Mitigated social supply chain risk** – Improved transparency on supply chain conditions • **Local employment** – Empowerment of R-strategies and new business opportunities • **Health and safety improvement** – Responsible sourcing and end-of-life treatment

Green Deal targets

- Financing and Investment
- Economic growth decoupled from resource use
- Climate Neutrality by 2050
- Zero Pollution Ambition
- Protecting Biodiversity
- Just Transition

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

1. Between reuse, remanufacturing, repurposing, and recycling

For more information, please visit Chapter 7, page 153 of the Full Document Value Assessment

With potential use cases such as data aggregation across passports enabled, the system-level, full-value-chain benefit is unlocked

Data aggregation unlocks significant system benefits

Beyond the benefits of individual battery passports, the **aggregation of data across all European battery passports promises significant system value**

For businesses, this aggregation entails 3 roundstream benefits:

1. Inform **upstream procurement strategies** on battery models or suppliers
2. Improve **internal understanding** for the effectiveness of circularity and decarbonisation measures
3. Create **downstream awareness** of product differentiation

Society and policymakers can also better **understand trends over time, supporting purchasing and policy decisions, respectively**

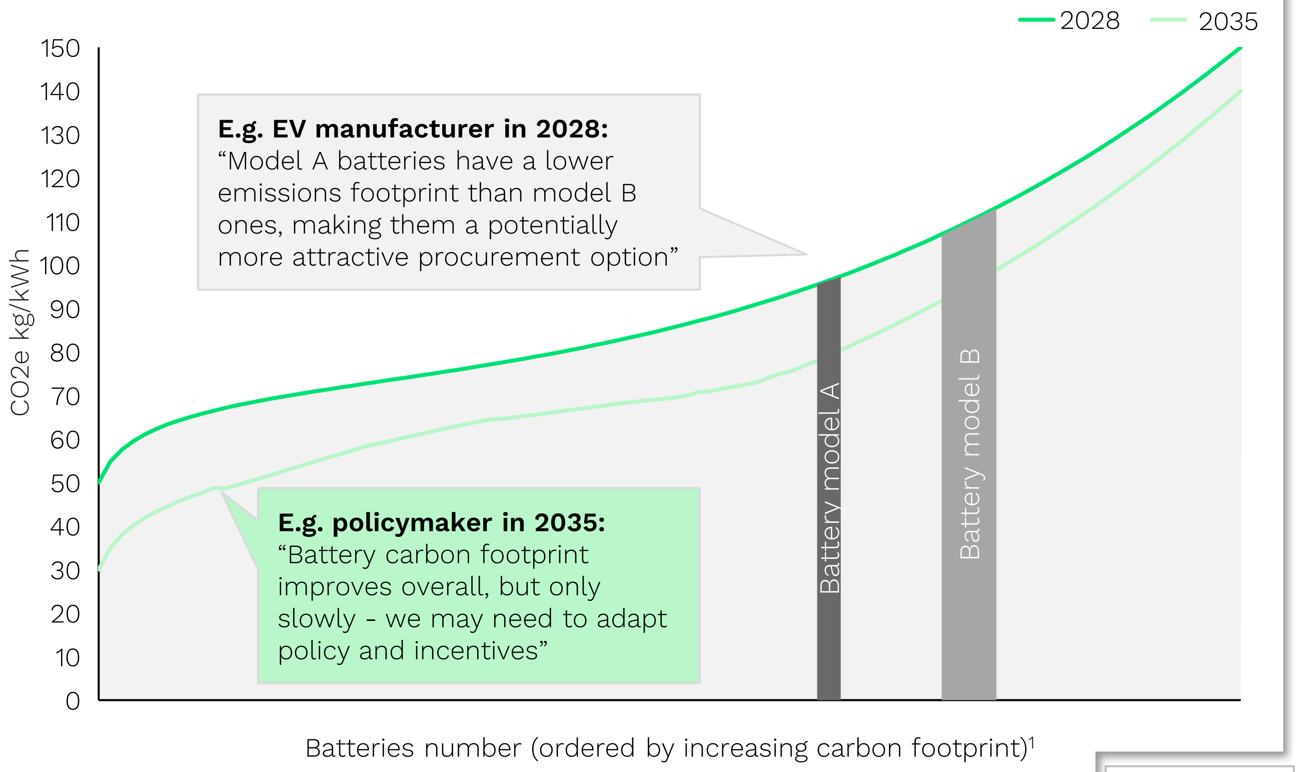
→ Aggregated data amplifies the ability and incentive for sustainability measures beyond that of individual passports

Note: For these benefits to materialise, the **EU needs to enable data aggregation across passports**
→ Visit slides 108-116 of the Full Document Value Assessment **for details on technical requirements**

Example of enabled visualisation via battery passport data aggregation

Distribution of carbon footprint across all EV batteries in the European market in 2028 and 2035

Indicative example chart only, with synthetic data



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

1. Distribution of carbon footprints would be available anonymously only. Other data attributes such as recycled content or expected lifetime could be similarly visualised.

For more information, please visit Chapter 7, page 153 of the Full Document Value Assessment

Societal value of the battery passport multiplies, if policymakers can use its insights to enhance policy design of other DPPs

	1. DPP conceptualisation	2. DPP deployment	3. DPP in action
Timeline	**Aug. 2023** Battery regulation is passed **First cornerstones**	**Today** **Learnings**	**Feb. 2027** Battery passport enters into force **Future learnings**
DPP implementation for batteries	a) Cornerstones of an **interoperable and standardised system architecture DPPs** **b) Analysis of sector/business-specific use cases to identify relevant product information for the DPP to create** social, economic and environmental value	a) Discussion of outstanding **clarification of detailed system requirements and data standardisation** b) Initial passport deployment effort mostly caused by **software development and data set-up throughout the value chain, where SMEs face highest burden**	**a) Adjustment and fine-tuning of system set-up and data provision** **b) Iteration of regulations to further optimise real-life use case deployment** and mediate **effort of battery passport implementation** c) Establish **transfer and implementation in further administrative processes and interoperability with other regions** (e.g. US, China)?

Note: While learnings from the battery passport are available, these will not be entirely applicable to other DPPs given differing sector contexts and timelines

For more information, please visit Chapter 7, page 161 of the Full Document Value Assessment

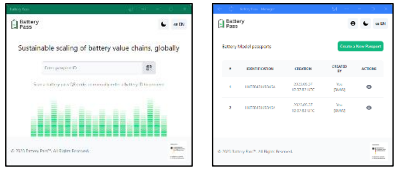
Supported by: Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

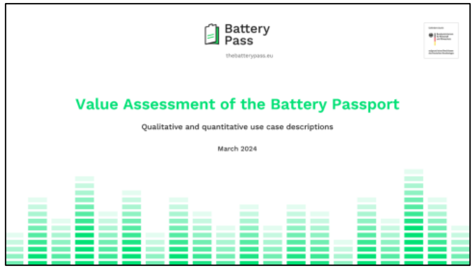
Sources and further reading

Back to overview

Please visit our other Battery Pass deliverables for more information on the battery passport

	Content Guidance	Technical Guidance	Demonstrator	Full Value Assessment
Objective	Provide guidance on content reporting requirements mandated by the EU battery passport	Provide overview to economic operators on technical standards	Provide platform integrating results on battery passport data, verify technological feasibility	Full analytical study on use cases and implementation efforts of the battery passport
Deliverables	• Content Guidance • Carbon footprint rules report • Data assurance report (tbp) • DIN Spec 99100 (tbp)	• Technical Guidance	• Software demonstrator • LEGO demonstrator • Data model (tbp)	• Use cases and benefits for EV batteries • Differences for LMT and industrial batteries • Challenges and implementation efforts





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 (1/4)

ADAC (2024): *E-Scooter im Nahverkehr – Verbot im ÖPNV*, accessible via: https://www.adac.de/news/verkehr-e-scooter-mitnahmeverbot-nahverkehr/, last accessed 12.08.2024

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

ADFC Baden-Württemberg (2024): *Fahrraddiebstahl*, accessible via: https://bw.adfc.de/artikel/fahrraddiebstahl, last accessed 12.08.2024

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

CIRPASS (2024): A study on DPP costs and benefits for SMEs, accessible via: https://cirpassproject.eu/wp-content/uploads/2024/02/CIRPASS-A-study-on-DPP-costs-and-benefits-for-SMEs-v1.0-1.pdf, last accessed 30.05.2024

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

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 (2/4)

European Anti-Fraud Office (2024): *OLAF and Polish Customs intercept illicit imports of 20 000 e-bikes*, accessible via: https://anti-fraud.ec.europa.eu/media-corner/news/olaf-and-polish-customs-intercept-illicit-imports-20-000-e-bikes-2024-02-07_en, last accessed 12.08.2024

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

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 (2021a): *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 (2021b): *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS*. The New EU Urban Mobility Framework, accessible via: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0811&qid=1644666550402

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

European Union (2024): *Directive (EU) 2024/1799 of the European Parliament and of the Council of 13 June 2024 on common rules promoting the repair of goods and amending Regulation (EU) 2017/2394 and Directives (EU) 2019/771 and (EU) 2020/1828* (Text with EEA relevance), accessible via: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024L1799

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

GDV (2024): *Fahrraddiebstahl: Alle Zahlen auf einen Blick*, accessible via: https://www.gdv.de/gdv/statistik/fahrraddiebstahl-statistik-versicherung, last accessed 12.08.2024

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

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 (3/4)

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

GRS Batterien Service GmbH (2023): *Erfolgskontrolle 2023 GRS eMobility gem. § 15 (1) und (3) Batteriegesetz*, accessible via: https://www.grs-batterien.de/fileadmin/Downloads/Erfolgskontrollen/EK23_GRS_eMobility_N.pdf, last accessed 12.08.2024

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

Ipsen (2024): *Diebstahl von E-Bikes – Polizei startet Kampagne "Protect your bike",* accessible via: https://www.ndr.de/home/niedersachsen/Diebstahl-von-E-Bikes-Polizei-startet-Kampagne-Protect-your-bike,kampagneprotectyourbike100.html, last accessed 12.08.2024

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

Mordor Intelligence (2024): *Marktgrößen- und Marktanteilsanalyse für E-Bike-Batterien* – Wachstumstrends und Prognosen (2024–2029), accessible via: https://www.mordorintelligence.com/de/industry-reports/e-bike-battery-pack-market, last accessed 12.08.2024

Morwinsky (2023): *INDUSTRIES & MARKETS. E-Scooter-sharing: market data & analysis*. Market Insights report by Statista, accessible via: https://de.statista.com/statistik/studie/id/144918/dokument/e-scooter-sharing-marktdaten-und-analyse/, last accessed 12.08.2024

Polizeiliche Kriminalprävention der Länder und des Bundes (2024): *Diebstahl – Räder richtig sichern*, accessible via: https://www.polizei-beratung.de/fileadmin/Medien/025-FB-Raeder-richtig-sichern.pdf

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

Statista (2024): *Absatz von E-Bikes in Europa von 2006 bis 2022*, accessible via: https://de.statista.com/statistik/daten/studie/1107790/umfrage/absatz-von-e-bikes-in-europa/, last accessed 12.08.2024

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 (4/4)

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

Velco (2024): *Schutz vor Diebstahl von Elektrofahrrädern, welche Lösungen gibt es?*, accessible via: https://velco.tech/de/schutz-vor-diebstahl-von-elektrofahrraedern-welche-loesungen-gibt-es/, last accessed 12.08.2024

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

ZIV – Die Fahrradindustrie (2023): *Marktdaten Fahrräder und E-Bikes für 2023.* In Kooperation mit dem VSF – Verbund Service und Fahrrad, accessible via: https://www.ziv-zweirad.de/wp-content/uploads/2024/03/ZIV_Marktdatenpraesentation_2024_fuer_GJ_2023.pdf, last accessed 12.08.2024

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.