The Digital Battery Passport

A major contributor to automotive sustainability and an opportunity to create value

Capgemini

Executive summary

The requirement for Digital Battery Passports (DBPs), introduced by the EU's 2024 Ecodesign for Sustainable Products Regulation (ESPR) and other legislation, affects the entire battery value chain and is relevant to many industries.

The requirement is extremely important for the automotive sector, since it applies to several categories of batteries used such as electric vehicle (EV) batteries. DBPs will be mandatory from February 2027, but some related obligations are already in force.

Responsibility for building, enriching, updating, and sharing the DBP resides with the "economic operator" (industrial player involved in the battery chain) that places the battery on the European market. This can be either the battery manufacturer or the automotive OEM, depending on manufacturing details. The responsibility may later pass to a player involved in repurposing.

DBP compliance presents significant challenges for the company responsible. First, cooperation and coordination are necessary at various levels. At industry level, a common "co-opetitive" framework with standards and rules is required to ensure compliance while not drowning battery value chain companies with a multitude of different queries. At a value chain level, coordination between data owners across the ecosystem is required to enable smooth and effective data transparency. At a company level, the whole organization will potentially need to be involved in DBP data collection or usage.

A second challenge is that of managing data. Both static and dynamic data need to be collected from across the value chain, and data reliability, safety, and confidentiality must be assured throughout the data lifecycle, along with technical cross-sector and cross-geography interoperability.

Like data management, technology solutions are crucial to successful DBP implementation. A range of solutions are becoming available – including both battery-specific offers and enablers that help companies build their own: A combination of "make" and "buy" is often best. It is also important to understand the underlying technologies (such as data spaces and blockchain).

Once the challenges are overcome, Capgemini believes the DBP offers an opportunity to create strategic, tactical, and operational value at each stage of the battery value chain.

To realize this, while achieving a smooth DBP implementation, it is helpful to view the DBP as a connected bundle of digital twins, spanning sourcing, corporate & manufacturing, and repurposing / end of life. Approaching the DBP in this way can create additional value.

To fully capitalize on the DBP, however, OEMs must synergistically combine advanced embedded algorithms with cloud computing and big data management. This helps the company to:

- Boost supply chain, sourcing, and engineering/R&D
- Augment service offers and improve product performance
- Enable predictive capabilities for second-life and end-of-life asset management

The ideas and approach discussed here are relevant to a wide range of traceability requirements in many industries and regions. By enabling personalization, efficiency, and transparency, Digital Product Passports (DPPs) and similar constructs have the power to meet evolving consumer expectations and to facilitate societal change.

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Introduction

The digital battery passport: a major contributor to automotive sustainability and an opportunity to create value

From 2035, no more new internal combustion engine vehicles will be allowed to be sold in the EU. That means batteries will be the largest contributor to a vehicle's environmental footprint. The EU's introduction of digital battery passports (DBPs) is a strategic response to the need to manage that footprint – ensuring high standards of sustainability, traceability, and transparency. The passports may serve as a "clean label" or confidence setter for consumers.

But DBPs are much more than that. At Capgemini, we are convinced that introducing them presents an opportunity for companies to generate significant value across the entire value chain.

Who should read this point of view?

A wide range of stakeholders

This point of view (PoV) focuses on the European DBP requirement, but much of our thinking applies to product passports in general – and to information needed in other contexts such as meeting traceability requirements, for example in the context of tariffs.

In terms of roles, heads of engineering and R&D will be interested because they are responsible for battery management systems (BMSs). Heads of IT will also be interested because they are tasked with keeping data flowing across systems. Heads of supply chain and procurement will want to read the PoV because they are responsible for static data coming from suppliers.

Relevance beyond the EU

Any automotive company wanting to sell to the EU will need to address DBPs, whether or not they are based in the EU. In addition, although the DBP is a world first in terms of its level of ambition, other key battery markets have started to introduce the concept, though not as a mandatory tool:

- In North America, the US has started regulating the origin of materials and batteries sold on its soil. For example, the Inflation Reduction Act (IRA) addresses retrieval and exposure of data on the provenance of these materials. We can expect a digital passport or other traceability tool to be imposed by the US government in the coming years.
- In Asia, since 2018, China has introduced a traceability system focusing on improving battery recyclability while providing clear information on battery maintenance, retirement, recycling, and re-use. After the EU Battery Regulation was passed, the Chinese government announced it would align with the European requirements to facilitate trade.

The regulations coming from the EU are likely to remain the most restrictive and demanding globally. Therefore, if a company meets the EU's requirements, it should be able to comply with other regulatory frameworks with relative ease.

Relevance to other industries

EV batteries are not the only ones that will require DBPs: They will be needed for all batteries exceeding 2kw/h. This includes light means of transport (LMT) batteries such as those used by e-bikes, e-scooters, and electric mopeds. Also affected are rechargeable industrial batteries like those used in airport ground equipment, industrial machinery, and stationary energy storage systems.

Most of the thinking in this report is applicable to all battery value chain players, whether in automotive or any other sector that uses batteries, such as energy storage and railways. We believe that all these actors will reap benefits from the DBP, albeit much further into the future in some cases.

> **"The battery passport, from the recycler's point of view, is a long way off. The battery passport will be mandatory in 2027, and these batteries will be coming to us long after that."**
>
> Sophie Schmidtlin – CTO at The Future is Neutral (Renault Group) at Paris Motor Show 2024

Relevance to other automotive requirements – and to society's future

EU regulations mean that future EVs will be equipped not only with DBPs but also with digital vehicle passports (DVPs). These too will be amenable to a similar approach to that described here.

Many other products will, in the future, require DPPs, and these could have a transformative effect, especially if combined with digital identities.

The concept of a digital identity comes from the idea of an open data ecosystem where individual entities – within a broader interconnected ecosystem – are integrated and centered around the user and automatically connect with one another. All this is regulated by an overall authority to guarantee compliance with GDPR and security requirements.

Combined with a digital identity, DPPs can facilitate the increased personalization and interconnectedness that consumers will increasingly expect and value. For example, with a digital-identity-augmented DVP, a vehicle can automatically match driver and vehicle digital identities to adjust all personal settings according to the driver's preferences.

Therefore, the concept of digital identity extends into the broader world of consumer experiences. In fact, the principles of transparency, personalization, and efficiency that underlie the DBP are already transforming the European market as a whole.

The DBP: definition, scope, and timeline

Overview of the regulatory background

The Ecodesign for Sustainable Products Regulation (ESPR) aims to make products sold on the European market sustainable by design, boosting their circularity, durability, reusability, upgradability, and repairability. This regulation builds on the Ecodesign Directive 2009/125/EC, extending it to virtually all physical products with richer criteria.

The ESPR introduces the concept of DPP for all regulated products, in order to provide product “handlers” with easy access to product information.

Mandatory from February 2027, the DBP will be the first DPP implemented in Europe. It is defined by the EU Battery Regulation, which specifies the ESPR framework for battery DPPs.

Responsibility for the DBP is defined in terms of “economic operators.” These include the battery manufacturer, authorized representative, importer, distributor, fulfillment service provider, or any other value chain player subject to obligations related to battery manufacturing, preparation for re-use, or repurposing/remanufacturing.

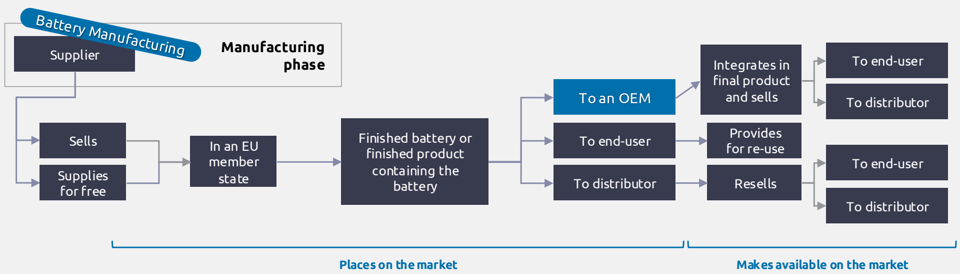
Responsibility for creating the passport, keeping it updated, transferring data, redeeming it, and making it available lies with those economic operators who place the battery on the EU market or who put it into service.

For instance, if an automotive OEM completes manufacturing of the battery (e.g. if it buys battery modules and integrates them into a pack), that OEM is considered to be placing it on the market and is therefore responsible for the DBP. On the other hand, if the OEM uses a battery that is already finished, it is the battery manufacturer who places it on the market and hence is responsible for the DBP.

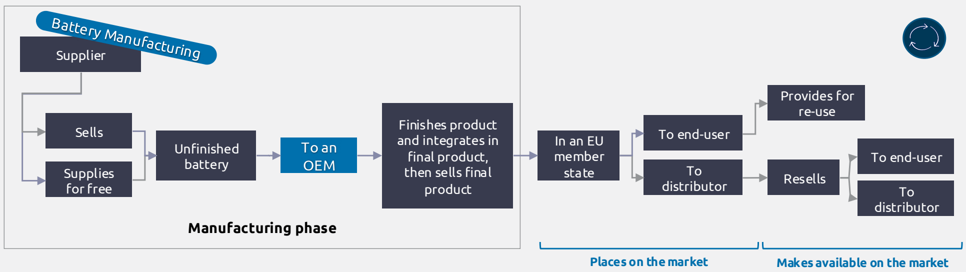
At the end of the battery’s life, and in second and subsequent lives, responsibility for the DBP may transfer to a player involved in repurposing.

Who is responsible for the Digital Battery Passport?

1 If the OEM is provided with a <u>finished</u> battery, the **battery manufacturer** is **responsible for the DBP**



2 If the OEM is provided with an <u>unfinished</u> battery, the **OEM** is **responsible for the DBP**



Definitions

- **Making available on the market:** any **supply of a battery for distribution or use** on the EU market in the course of a commercial activity, whether in return for payment or free of charge
- **Placing a battery on the market:** making a battery available on the EU market for the first time

Putting into service

- The **first use, for its intended purpose**, in the European Union, of a battery, **without having been previously placed on the market**

End user → Use for the first time → Finished battery or finished product containing the battery → For its intended purpose (defined by the manufacturer)

The DBP framework includes data categories and associated data points to ensure comprehensive traceability and transparency. At the **battery model level**, data categories include:

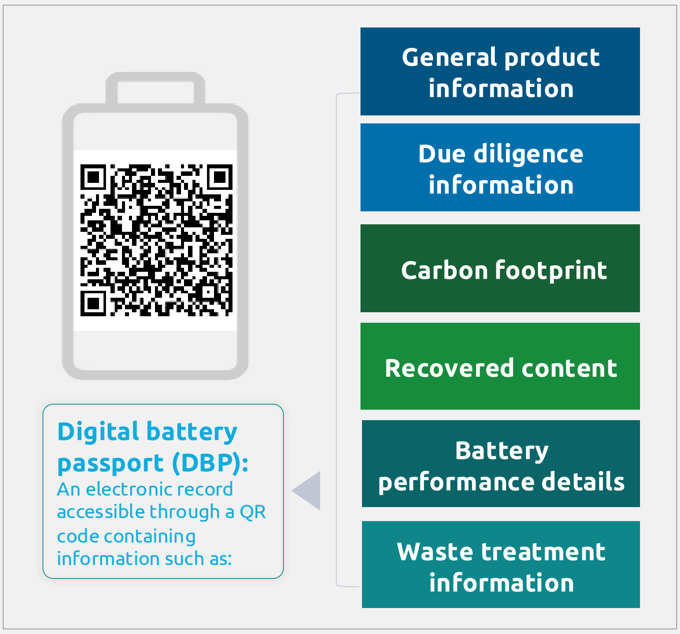
- **General battery and manufacturer information**, such as battery type, model, and manufacturer details
- **Material composition**, detailing the types and percentages of raw materials used
- **Compliance certifications**, covering adherence to regulatory and safety standards

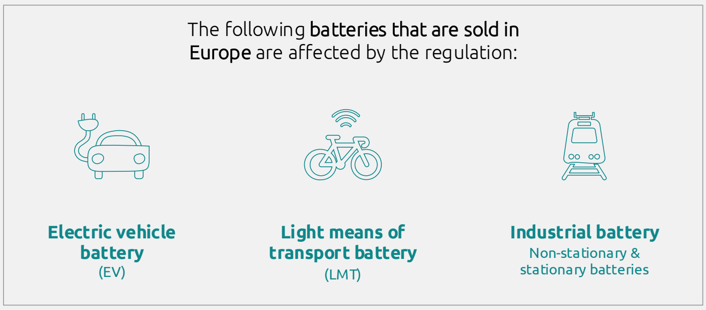
At the individual battery level, data categories focus on:

- **Production details**, including batch numbers and manufacturing dates
- **Performance history**, such as charge/discharge cycles and efficiency over time
- **End-of-life information**, which encompasses recycling history and remaining useful life

By maintaining a clear distinction between model-level and individual-level data, the framework enables robust lifecycle management and supports sustainability goals.

Digital Battery Passports provide transparency throughout a battery's lifetime to increase collaboration and enable circularity





The economic operator* who places the battery on the market or puts it into service is responsible for storing and making the Digital Battery Passport data available

* Actor who is subject to obligations in relation to the manufacture, preparation for re-use, preparation for repurposing, repurposing or remanufacturing of batteries, **the making available or the placing of batteries on the market**, including online, or the **putting of batteries into service**

The DBP in a nutshell

The DBP is an electronic record of a battery, accessible through a QR code on a battery label. It stores and provides a comprehensive data set collected throughout the battery's lifecycle. This includes data related to production, testing, usage, maintenance, performance, carbon footprint, and recycling.

The full version of the DBP will be mandatory from early 2027. However, some related obligations are already in force, including, since 2024, the communication of battery electrochemical performance and durability parameters to battery end-users via a document accompanying the battery and the BMS.

Three major developments are taking place in 2025: (1) the definition of the method used to compute the battery's carbon footprint, (2) due diligence requirements coming into force, and (3) the start of communication of waste battery treatment information.

Data is communicated according to the regulatory timeline to the public and/or public authorities and notified bodies. Communication is through documentation accompanying the battery, technical documentation demonstrating battery compliance, or the BMS.

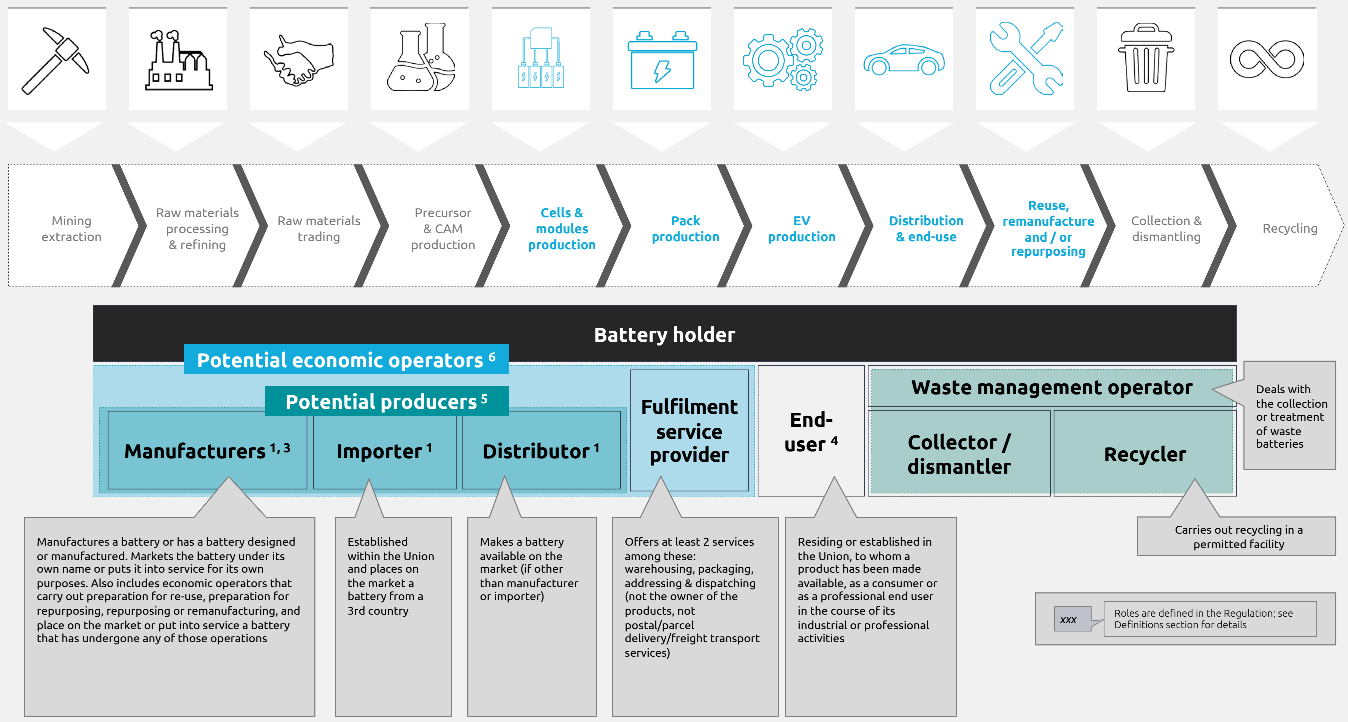
Battery types in scope

The EU Battery Regulation applies to all categories of batteries as defined by the European Commission (see Definitions section): portable batteries, starting, lighting and ignition (SLI) batteries, LMT batteries, EV batteries, and industrial batteries. However, only LMT, EV, and industrial batteries require a DBP starting early 2027.

Impact on value chain players

As already noted, it is the economic operators placing the battery on the EU market or putting it into service who are responsible for storing the DBP and making it available. However, all value chain players are affected by the Regulation. For example, the producer has considerable obligations, especially with respect to extended producer responsibility. This is outside the scope of the current PoV, however.

The EU Battery Regulation assigns specific obligations to each member of the value chain



[1] Or their representative

[2] Excludes actors not established in the EU

[3] Includes actors preparing for re-use, preparing for repurposing, repurposing or remanufacturing, and placing on the market or putting into service a battery that has undergone any of those operations

[4] The end-user can be the economic operator if they are declared 'authorized representative'. It means any natural or legal person established in the Union who has received a written mandate from a manufacturer to act on its behalf in relation to specified tasks with regard to the manufacturer's obligations under Chapters IV and VI

[5] Any manufacturer, importer or distributor or other natural or legal person that either: i. is established in a Member State and manufactures batteries under its own name or trademark, or has batteries designed or manufactured and supplies them for the first time under its own name or trademark, within the territory of that Member State; ii. is established in a Member State and resells within the territory of that Member State, under its own name or trademark, batteries manufactured by others, on which the name or trademark of those other manufacturers does not appear; iii. is established in a Member State and supplies for the 1st time in that Member State on a professional basis, batteries from another Member State or from a third country; iv. sells batteries by means of distance contracts directly to end-users, whether or not they are private households, in a Member State, and is established in another Member State or in a third country

[6] Manufacturer, authorized representative, importer, distributor or fulfilment service provider or any person subject to obligations in relation to the manufacture, preparation for re-use, preparation for repurposing, repurposing or remanufacturing, making available or placing of batteries on the market, or putting of batteries into service

Overcome the challenges of DBP compliance

Battery value chain stakeholders face a range of challenges in understanding and implementing the EU Battery Regulation. Here, we describe those challenges and recommend some ways to overcome them.

Building an integrated framework for ecosystem working

To guarantee successful implementation of the DBP, a common cross-industry "co-opetitive" framework is required. Companies affected by the requirement need to coordinate – with competitors, across their own value chain, and internally.

> **"...there is a real need for stakeholders to get together and collectively build the value chain, but also so that the data can start flowing."**
>
> Grégoire Sarrail, Technical Director, Mecaware
> at Paris Motor Show 2024

Coordinating with competitors

To ensure compliance while not drowning battery value chain companies with a multitude of different queries, common standards and rules should be agreed. Battery industry consortia are already working on this, publishing their findings as they go along.

For the automotive industry, the most important consortia are the Global Battery Alliance (GBA), Battery Pass, and RECHARGE. Their activities include publications to explain and interpret the Regulation, working groups around DBP implementation, and proofs of concept (PoCs) launched by their members (usually EV battery value chain players).

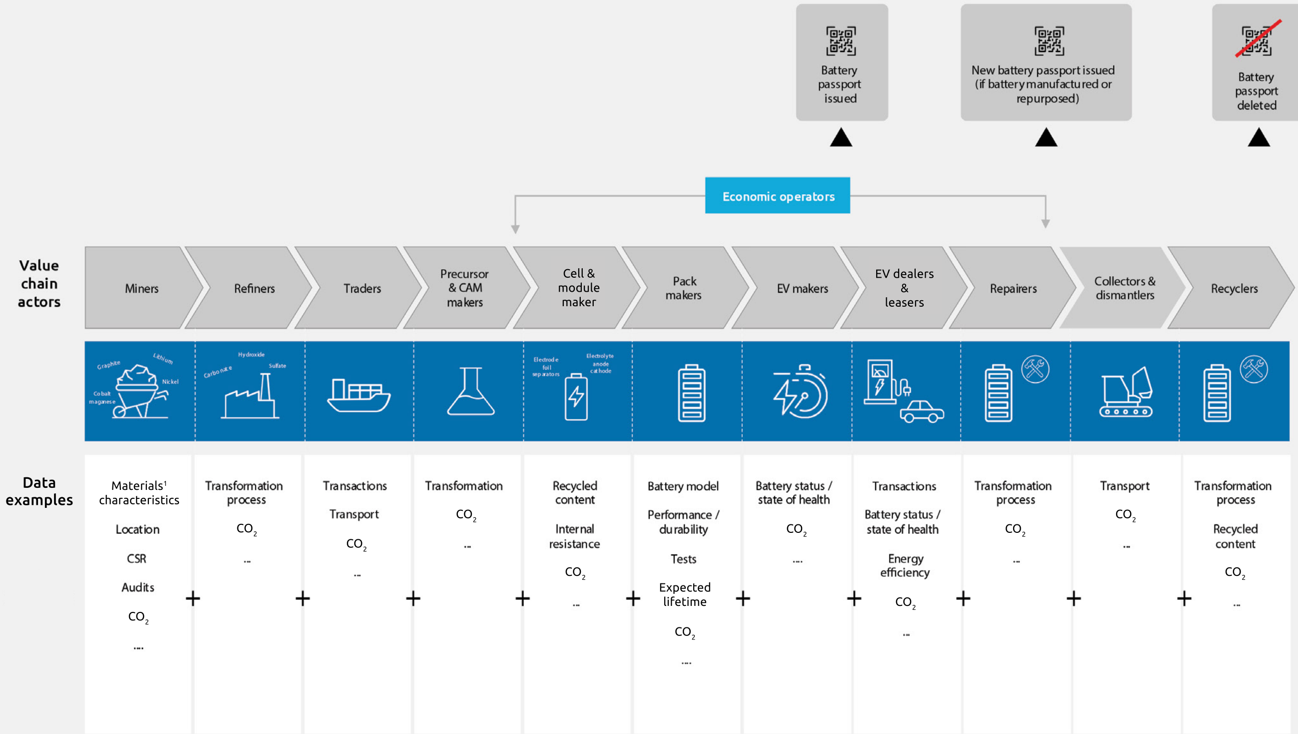
These consortia are valuable for EV battery value chain players because as well as creating shared standards and rules, they facilitate alignment on interpretations and share learnings from their research. They also position the industry to make strong recommendations to the European Commission.

Coordinating across a company's own value chain

A fully operational DBP will require collecting data from upstream actors like traders and miners, especially due diligence data. It will also require collection of downstream data during the battery's use – e.g. for state of health monitoring, and to manage battery life.

On top of the technical challenges, this type of coordination brings organizational and communication requirements: defining roles and responsibilities, agreeing on data granularity, ensuring industrial confidentiality without compromising regulatory compliance, identifying and onboarding the right actors, and more.

For the Digital Battery Passport to become a reality, coordination across the entire value chain is required



Coordinating internally

The DBP requires the involvement of the whole organization. This is true of EV battery value chain players in general, but especially for economic operators with primary responsibility for the DBP; they need to collect data from across their own systems in addition to the rest of their value chain.

For instance, to perform the Conformity Assessment Procedure, quality teams will have direct access to quality test results and evidence of quality monitoring systems. However, they will need to coordinate with the engineering and manufacturing departments who own product and production consumption data needed to complete the picture.

Therefore, implementing the DBP will require a dedicated organization with structured, clear, and efficient governance. The lead department can be chosen for:

- Its transversal role – e.g. sustainability, traceability
- Its ownership of key data points – e.g. procurement, engineering/R&D – or
- Its responsibility for corporate commitments – e.g. quality, sustainability, aftersales.

DBPs involve an entire organization, but the overall governance can be owned by different teams

Managing data

The DBP's purpose is to make available up-to-date static and dynamic data with differentiated access rights. A challenge here is the lack of precise technical guidelines within the Regulation.

We are expecting further details from the European Commission about the recommended technical standards to build a DBP. The European Committee for Standardization (CEN-CENELEC) and the European Telecommunications Standards Institute (ETSI) have been mandated to define these standards and the associated protocols.

However, given the tight regulatory calendar for deployment, we believe companies cannot afford to wait for these recommendations. They must start building their DBPs now.

This entails collecting static and dynamic data from across the value chain, ensuring data reliability, safety, and confidentiality throughout the data lifecycle, and ensuring cross-sector and cross-geography interoperability.

Collecting static and dynamic data from across the value chain

Static data

Static data can relate to any aspect of the battery that will not vary frequently or continuously during use – e.g. original power capability, raw material quantities, or recycled content. Although raw material information can change during repairs, this evolution is not regular enough for this data to be counted as dynamic.

Miners, traders, refiners, and cathode active material (CAM) precursor producers provide static data mainly relating to due diligence and carbon footprint. According to the latest regulatory draft publications, secondary datasets will be enough to cover upstream data for carbon footprint.

However, players active in battery manufacturing – module, cell and pack producers, remanufacturers, and sometimes EV makers – will be the main static data providers, giving information on battery electrochemistry, characteristics, recovered content, and waste treatment information.

Dynamic data

Dynamic data presents significant technical complexities. It relates to information that varies regularly and continuously during the battery's use – e.g. capacity fade, state of certified energy, or internal resistance increase.

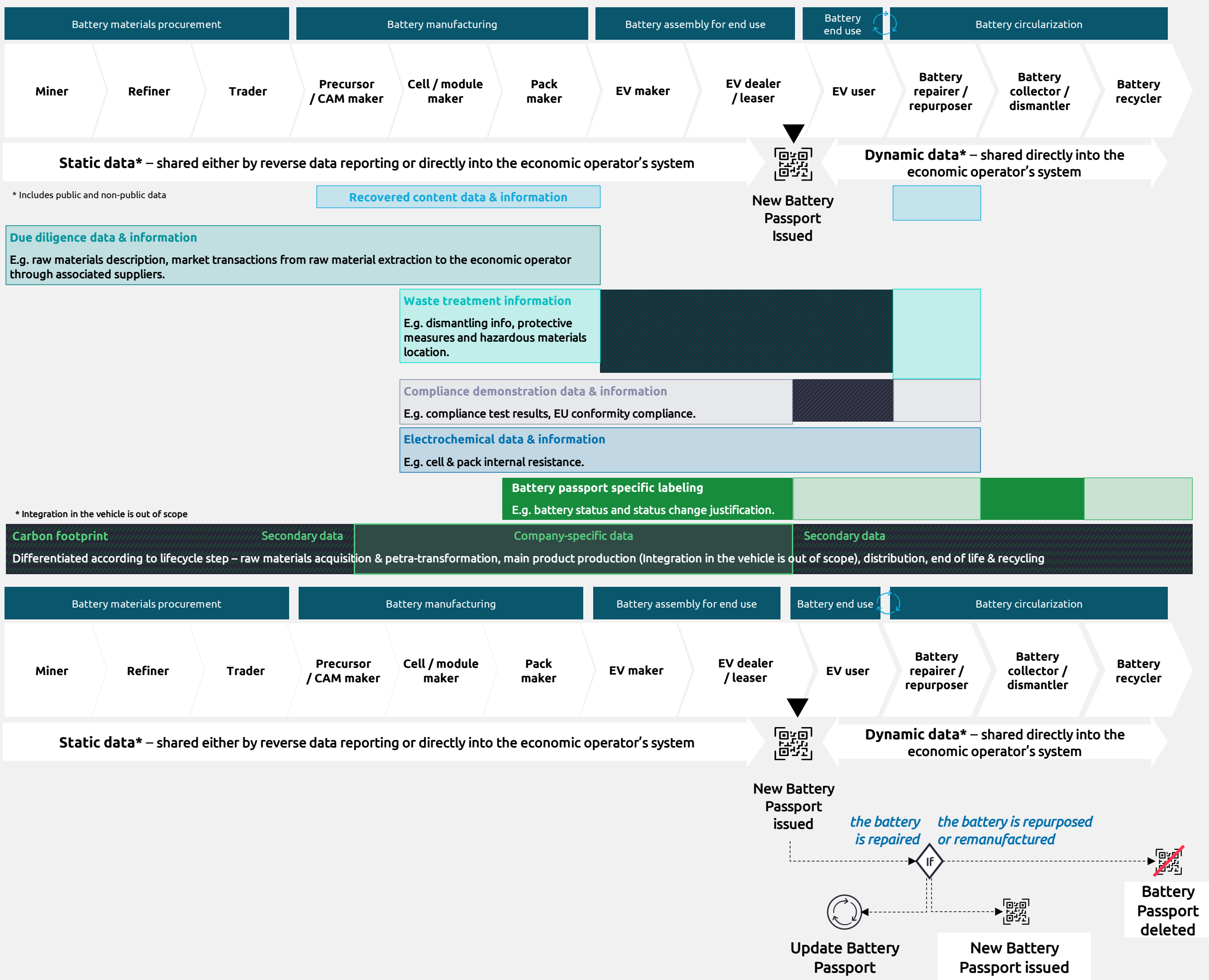
The EU Battery Regulation does not define a minimum update frequency for dynamic data, but recommends daily updates as a minimum. Defining this frequency is strategic for economic operators managing the DBP to anticipate the volume of data flows they will need to manage for each battery in circulation – especially as most dynamic DBP data is needed at the individual battery level.

The BMS will be used to collect dynamic data. Today, it is mainly accessed via wired connections once a year, during vehicle controls. For a higher refresh frequency, it will be necessary to connect the BMS wirelessly.

Wireless connections are achievable via GSM chips and a dedicated cloud. However, this type of architecture can be quickly overwhelmed by large data volumes. A better solution may be that adopted for software defined vehicles. Here, only data that is identified as useful within the controller area network (CAN) is sent to the cloud.

Dynamic data will largely be provided by players who control the BMS – i.e. EV makers, potentially EV distributors and leasers, and remanufacturers. In the case of batteries sold for energy storage purposes, battery pack makers normally control the BMS, and should therefore provide the dynamic data.

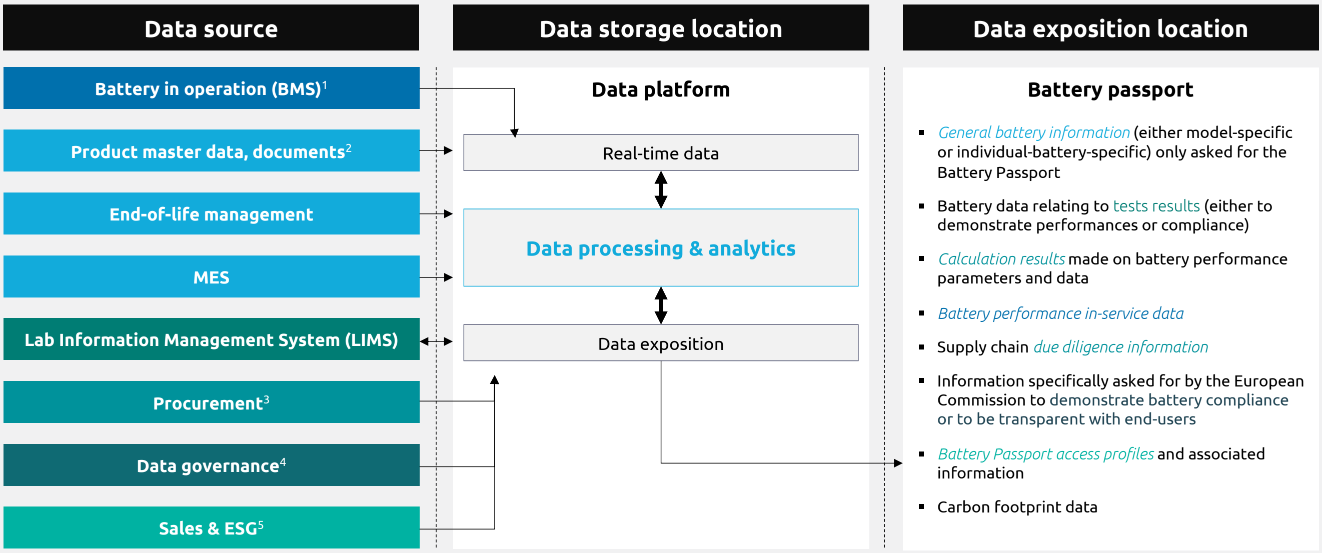
DBPs involve an entire organization, but the overall governance can be owned by different teams



Each player will have to connect multiple tools within their IT landscape to find the right information, consolidate it, and push it to the responsible economic operator's DBP system.

For instance, any consumption data that could be useful for carbon footprint calculation should be available in manufacturing systems like the manufacturing execution system (MES) or the product lifecycle management (PLM) system. Battery design schematics can usually be found in engineering systems managing product master data – for example, enterprise resource planning (ERP) systems.

Economic operators will need data that is scattered across their systems



1. Including customer battery integration projects, BMS telematics & analytics
2. Including product labeling & packaging
3. Including supplier due diligence, supply chain transparency & integrity
4. Including data privacy, security & localization
5. Including product registration, customs & compliance, compliance auditing & certifications, corporate ESG certifications

Ensuring data reliability, safety, and confidentiality throughout the data lifecycle

DBP data must comply with regulatory requirements – it will undergo audits to meet a specific quality standard. It must also comply with data owners' requirements, e.g. for IP protection and data sovereignty. All this must happen in a secure environment. Again, meeting these requirements can be especially challenging in the case of dynamic data because it is constantly flowing.

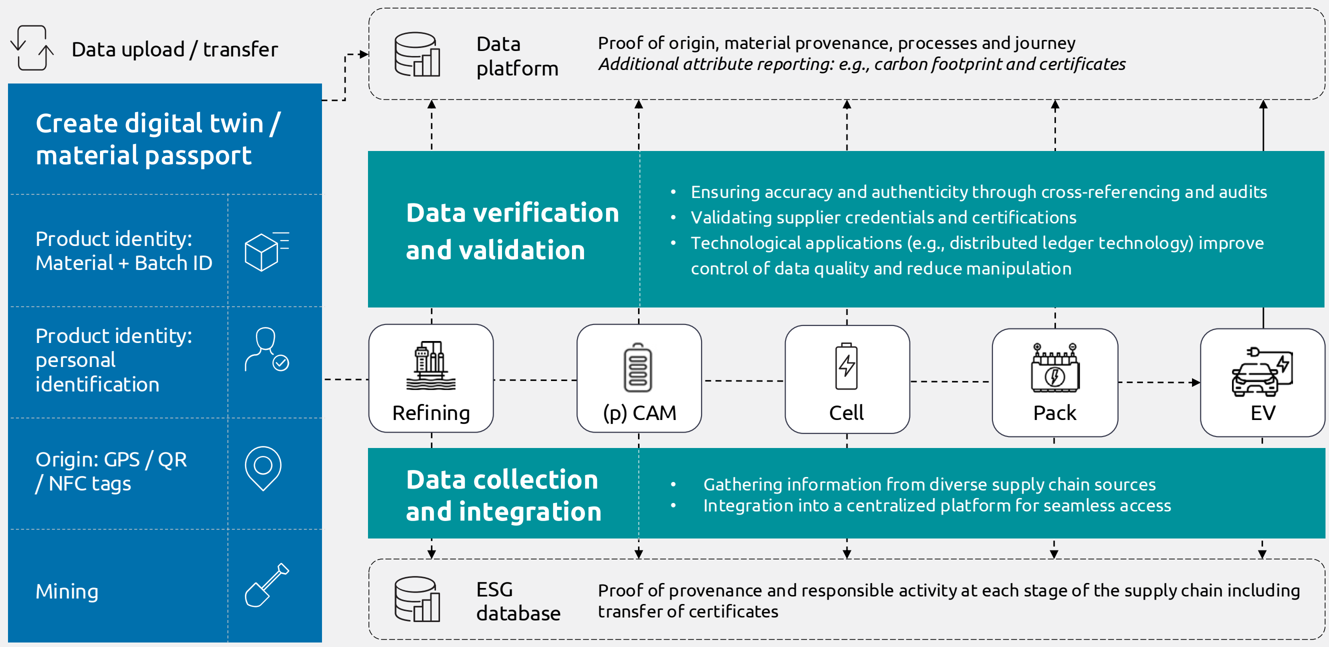
Data reliability

The data collected must be accurate and reliable to meet the EU's objective of ensuring that public and stakeholders can make well-informed decisions. The implementation of transparency tools and quality control procedures is therefore crucial.

The DBP requires a significant amount of static component data. An upstream value chain transparency tool can provide a clear view of the battery's entire cradle-to-gate course, supplying all the required static information. This will facilitate efficient supply chain traceability – something that today usually requires a lot of manual processing that is both time consuming and expensive.

The ESPR's solution assigns a unique digital identifier to each battery. This allows economic operators to follow up on the life events of each battery sold, and facilitates DBP transfers between economic operators, as the static information will still be required in the next life.

Upstream supply chain material traceability and emission tracking



Source: Technical Guidance, Battery Pass, 2024
https://thebatterypass.eu/assets/images/technical-guidance/pdf/2024_BatteryPassport_Technical_Guidance.pdf

Finally, data must be consistent between economic operators for interoperability. Standards and protocols can provide common ground.

Data accessibility, system security, and business confidentiality

Battery data raises security and privacy questions – e.g. about how to ensure retrieved dynamic data is anonymized, and supplier IP information is protected. Therefore, non-public data access must be controlled for each data attribute by the economic operator with overall responsibility for the battery. Breaches of privacy, in particular, can lead to significant reputational damage.

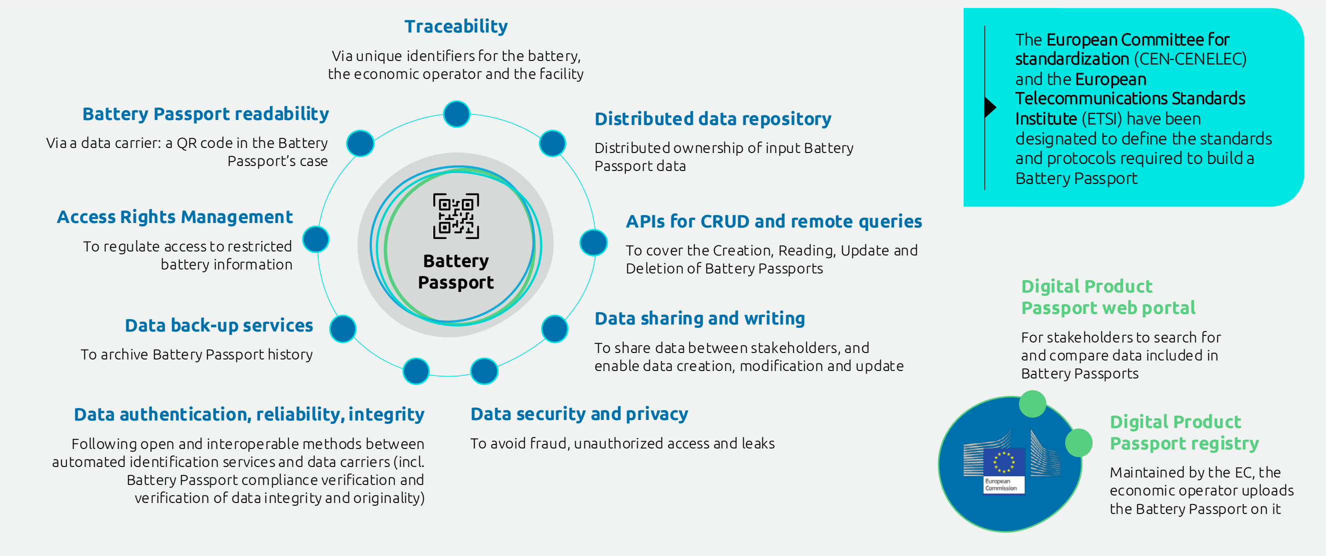
Cybersecurity is a major concern. The DBP must be protected from unauthorized access, cyberattacks, and other cyberthreats. Appropriate security safeguards must be in place across software development, data platforms, and data lifecycle management – e.g. firewalls, virtual private networks, vulnerability management, intrusion detection and prevention, and virus protection.

To minimize the additional burden of guaranteeing data security and cybersecurity, we strongly recommend that economic operators build on existing technical standards as much as possible. As the dynamic data is being transmitted from the battery itself, this is an excellent time to review the security of BMSs while also ensuring that the DBP does not create vulnerabilities.

Ensuring technical cross-sector and cross-geography interoperability

The ecosystem framework approach described earlier is key to the definition of technical DBP standards and protocols. But DBP standards need not prevent the continued use of pre-existing standards.

DBP functionality and standards as defined by the European Regulatory Framework, coming into effect from January 2026



Identifying, implementing, and leveraging the right solutions

How to approach "make or buy" decisions

Before searching for an off-the-shelf DBP solution, we recommend that economic operators define their priorities in terms of strategic use cases – compliance-led, added-value-led, or both. A study of this kind will generate efficiencies during PoCs and further digital solution selection processes, while helping the company to organize DBP implementation around clear, structured governance.

Many economic operators wonder if they should build their DBP themselves or outsource the work. We believe a hybrid approach is preferable as it minimizes the need for development from scratch. It does this by leveraging existing infrastructure within the economic operator's IT ecosystem wherever possible, while integrating market-recognized technology solutions to fill any gaps.

For instance, compliance necessitates generating a unique, verifiable identifier associated with a QR code for each battery. If the company has not already implemented a solution for this, it can look for a market solution.

We believe a "best of breed" approach is preferable to combine recognized market solutions with a company's experience and expertise

Make = developing one's own solution

Progressively renovate an existing IT system by introducing new elements, and by leveraging the company's catalog

Hybrid = integrating the "best of breed"

Re-engineer the current IT system into a new To-Be architecture by leveraging most mature bricks

Buy an "off-the-shelf" IT solution to integrate with the current sources and applications

Recommended

Buy = buying an "off-the-shelf" solution

Enable outsourcing of the activity and part of the governance (BPO = Business Process Outsourcing)

Potential approach

01 Adapted market analysis

- Enrich and update existing benchmarks on Battery Passport solutions
- Specify and adapt market solutions analysis to the company's strategic needs

02 Architecture scenarios evaluation

- Identify architecture scenarios according to the company's needs, functional and technical feasibility, etc.
- Evaluate each scenario with pre-defined criteria – e.g. functional coverage, interoperability, alignment with the company's strategy.

03 Target roadmap selection

- Combine adapted market analysis with evaluation of architecture scenarios to recommend a top trajectories for Battery Passport implementation at the company

Following this rationale, many market DBP solution providers offer modular solutions. For example, some provide services around the creation of a unique and secured DBP and associated QR code, while others support data collection and preparation to populate the electronic record.

Underlying technologies

Behind the modular service portfolio, solution providers mainly leverage two technologies, together or separately: data space and blockchain.

Data space

A collaborative data space is a federated, open infrastructure for sovereign data sharing, based on common policies, rules, and standards. Data collection, upload, and updates are done through International Data Space (IDS) connectors which operate in the federated environment. This type of infrastructure provides standardized, secure, and compliant data exchanges, in addition to data sovereignty and interoperability. However, many data spaces are rather centralized, potentially leading to single points of failure. Moreover, their implementation is complex as it implies onboarding many stakeholders within the federated environment – i.e. in terms of technical standards and rules in use within the data space.

Prominent in this area are Catena-X and the International Material Data System (IMDS); these should be seen as mutually complementary when it comes to aggregating data on a battery's carbon footprint. While Catena-X offers an approach that is already widely used in automotive, plus a data template for DBPs, IMDS's hotspots are invaluable for guiding eco-design.

	Feature	IMDS	Catena - X
01	Purpose	Material compliance & tracking	Secure PCF & emissions data exchange
02	PCF Support	Indirect (through material data for LCA)	Direct (structured PCF data exchange)
03	Industry	Automotive only	Automotive + broader supply chains
04	Data Type	Material composition	PCF, emissions, and supplier data
05	Integration with LCA Tools	Requires external tools like SimaPro, GaBi	Can integrate with carbon accounting tools
06	Real-time PCF Data Exchange	❌ No	✅ Yes
07	Standard Compliance	EU REACH, ELV	ISO 14067, GHG Protocol, PACT
08	Supplier Engagement	Mandatory for automotive suppliers	Encourages full supply chain participation

Another important player here is the Industrial Digital Twin Association (IDTA), which provides a standard on how to add semantic information to a data point: the Asset Administration Shell (AAS). An approach called aspect models is used to describe data points in relation to each other. Every company can define its own sub-models – a huge advantage for meeting regulatory requirements because a sub-model only needs to be described once by a working group to be usable by any stakeholder in the value chain. The data is made available through links to the source system, significantly reducing the need to integrate data models from different systems. The IDTA has also published an AAS model for battery passport usage.

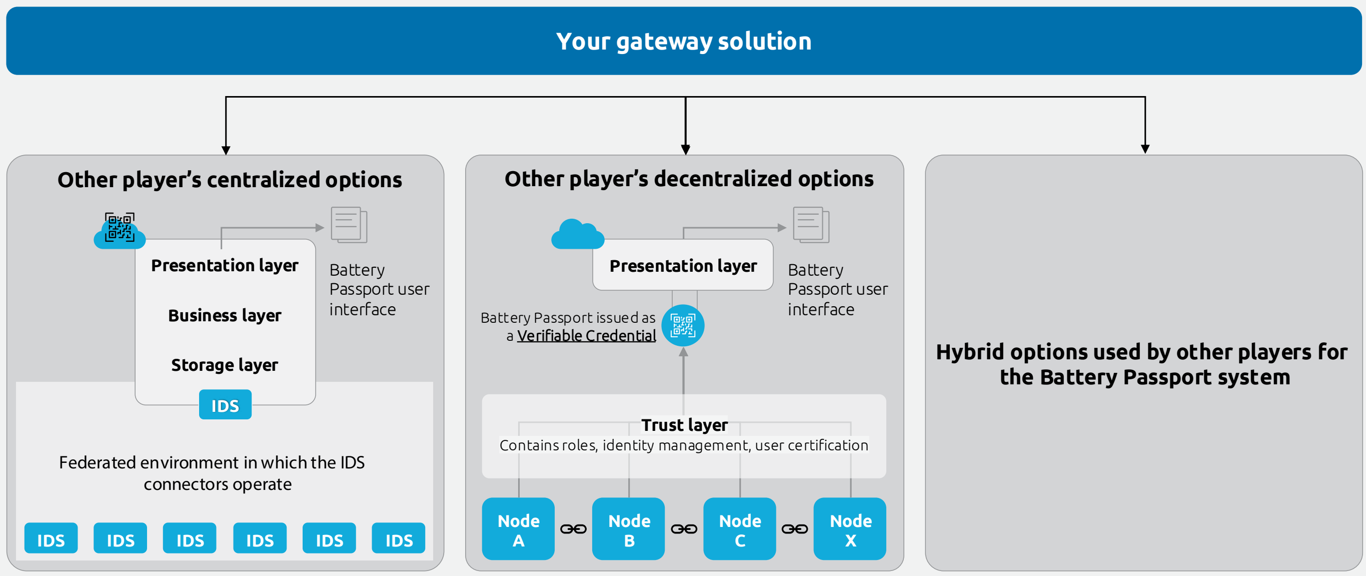
Together, the AAS and Catena-X concepts provide a possible framework for a standardized data model, combining semantics and a network for exchanging data. Open source software like Basyx guarantees the scalability of this solution.

Blockchain

The second option is to develop or join a blockchain solution. Here, the DBP would be issued as a verifiable credential, and blockchain technology would enable traceability and identity access management. This option is decentralized and provides immutability and transparency while enabling smart contracts.

However, blockchains are very energy-intensive, making them a questionable choice in an era of decarbonization and energy efficiency. Moreover, integration with existing systems can be challenging, and blockchain's transparent nature might raise issues around sensitive information. Finally, as blockchain is participative, if its users do not maintain it, it may break down.

There will be several co-existing DBP systems to be managed



Passport specific solutions versus enabling solutions

Two main types of solutions are available on the market: battery- or product-passport-specific solutions and enabling solutions.

Passport-specific solutions

Off-the-shelf solutions, compliant by design, reduce the amount of development work needed. However, although providers aim to offer modular and tailored solutions, this option generally requires the intervention of a third-party integrator. In our opinion, Siemens, Spherity, Circulor, and Minespider fall into this category.

Enabling solutions

Without a DBP-specific solution, more in-house development is needed. However, if enabling solutions have already been implemented within the company's IT ecosystem, they are probably already collecting, consolidating, verifying, or exposing – fully or partially – DBP data, providing a useful basis for that development.

Whatever decision an economic operator makes – i.e. make vs. buy vs. hybrid, specific solutions vs. enabling solutions – it must integrate enabling solutions into its final architecture landscape. AWS, SAP, Dassault Systèmes, and Microsoft are among the providers of enabling solutions.

Realize the opportunities of DBP

So far, this PoV has mainly focused on implementing the DBP to achieve compliance with the Regulation. However, at Capgemini, we believe DBP implementation is a real opportunity, not just an obligation.

Treat the DBP as a bundle of digital twins

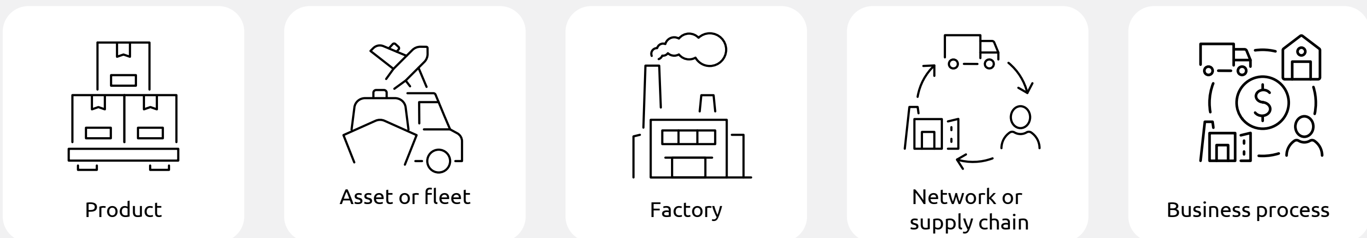
Because the DBP requires static and dynamic data from every step in the battery's value chain, it could be considered as a digital twin. However, it is a complex, multi-dimensional twin that must address value chain, battery components, and stakeholder engagement.

Therefore, it would be more accurate to consider the DBP as a connected bundle of digital twins, covering key value chain steps and the associated battery components. This view paves the way for a variety of additional applications for the DBP and its associated data and solutions.

There are multiple types of digital twins

Across different industries...

and for different systems

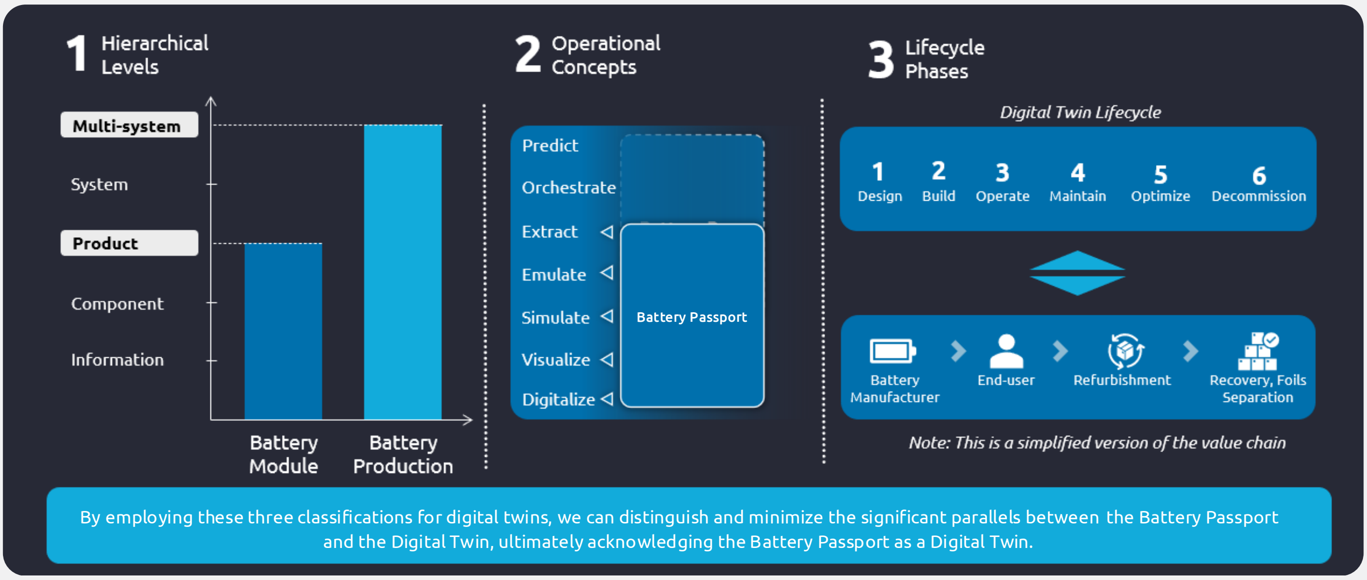


Digital twins serve **many purposes**; there is **no single digital twin.**
Different stakeholders interact with digital twins **from different perspectives** and **derive different types of value.**

Required functionalities overlap with digital twin characteristics

The proximity between DBP and digital twin technology can be seen when analyzing the passport's functional requirements from the perspective of digital twin characteristics.

DBPs can be described within the hierarchical framework used for digital twins



Level 1 – information twinning: The DBP is a digital representation of information and data for a physical product.

Level 2 – component twinning: The DBP provides partial digital representations of individual components within the battery – e.g. cells, casing, electrodes.

Level 3 – product twinning: The DBP provides a partial digital representation of how the battery's components interact.

Level 4 – system twinning: The DBP integrates data from the entire battery production process, lifecycle management, and recycling workflows.

Level 5 – multi-twinning system: The DBP integrates data (e.g. on manufacturing, supply chain, usage, recycling, and environmental impact) from multiple systems

The DBP as a composite digital twin

As the DBP will consolidate data throughout the battery value chain and during a battery's many lives, it can be seen as a composite of three digital twins: sourcing, corporate & manufacturing, and repurposing / end of life.

If an economic operator approaches the DBP in this way, and enriches it with the right data, additional uses can be unlocked and additional value created. For example:

- The sourcing digital twin should include due diligence information. This could be used to support compliance beyond the EU Battery Regulation (e.g. the Corporate Due Diligence Directive, CDDD), check supplier compliance, manage sourcing risks, optimize sourcing strategy and processes, and optimize storage.
- The corporate & manufacturing digital twin should include battery carbon footprint and manufacturing information. This could be used to support compliance beyond the EU Battery Regulation (e.g. the Directive on Corporate Sustainability Reporting, CSRD), optimize battery quality, predict maintenance needs, and optimize in-plant product flows.
- The repurposing / end of life digital twin should include recovered content and waste treatment information. This again could support compliance beyond the EU Battery Regulation (e.g. extended producer responsibility), optimize battery status change from main use to waste and the associated second-life scenarios, and facilitate battery recycling.

Let's look at an example to see how this approach can unlock business value. Currently, organizations recycle only one-third of batteries. However, according to the International Lead Association (ILA), in Europe and the US 99% of lead batteries are collected at end-of-life and recycled. In 2022, all EU countries achieved the target of 65% recycling efficiency for lead-acid batteries and accumulators, with many achieving recycling efficiencies up to 90% . Smart use of the DBP, harnessing the concept of a composite digital twin, could enable these standards to be achieved across the board.

Use the DBP to create business value

Companies can use the new DBP to create value for themselves right along their value chain, including battery materials sourcing, battery manufacturing and integration, battery usage, and battery second life & recycling. This value can be delivered at strategic, tactical, and operational levels.

Potential value for automotive OEMs

Automotive OEMs have characteristics that position them uniquely to maximize the benefits of the DBP. These characteristics include:

- Deep battery expertise: OEMs' in-house battery experts understand the intricate complexities of battery technology, chemistry, and performance.
- Data science & infrastructure: OEMs have invested heavily in data science teams, robust data infrastructure, and sophisticated data management strategies.
- Customer-centric service design: OEMs design and deliver a wide range of services for diverse customer segments (B2C, B2B, and B2B2x), equipping them to integrate DBP data into value-added offerings.

Technical elements that must be integrated to unlock DBP value

To fully capitalize on the DBP, OEMs must synergistically combine two main elements:

- **Advanced embedded algorithms:** Sophisticated algorithms are embedded within the BMS, engine control unit (ECU), and other vehicle components to manage data and optimize hundreds of battery parameters. These algorithms can facilitate collection of data from the BMS and its transmission to the cloud via vehicle connectivity features. Enhancing these algorithms with AI capabilities and upgrading control units will enable real-time data processing at the edge.
- **Cloud computing & big data management:** Cloud platforms provide secure data collection, storage, and the processing power necessary to analyze vast datasets, identify patterns, and perform predictive analytics. These capabilities are vital for the DBP because a connected BMS generates a continuous stream of data related to battery performance, usage, and environmental conditions.

Embedding AI at the edge (within the BMS) enables intelligent data pre-processing and optimization before transmission to the cloud, reducing latency and transmission costs while enabling near-real-time use cases. This hybrid approach of edge plus cloud computing can maximize the value extracted from the collected data.

> **"Every day, EVs generate millions of data points, and with this data, we have an incredible opportunity to enhance safety, reliability, and sustainability. At Accure, we harness the power of ML [machine learning] and physics-based models in the cloud to unlock the full potential of these vehicles, helping automotive manufacturers extend battery life and ensure safer, more efficient operations."**
>
> Dr. Kai-Philipp Kairies, Founder and CEO, Accure Battery Intelligence

Use cases for delivering DBP value in automotive

The integrated approach described above will ensure that companies have not only the data required for the DBP, but also the real-time analytical capabilities to immediately leverage its value. The figure below maps relevant use cases from the Regulation to the added value that can be gained from it at all levels of the business, and right across the value chain.

From the automotive OEM's point of view — OEM

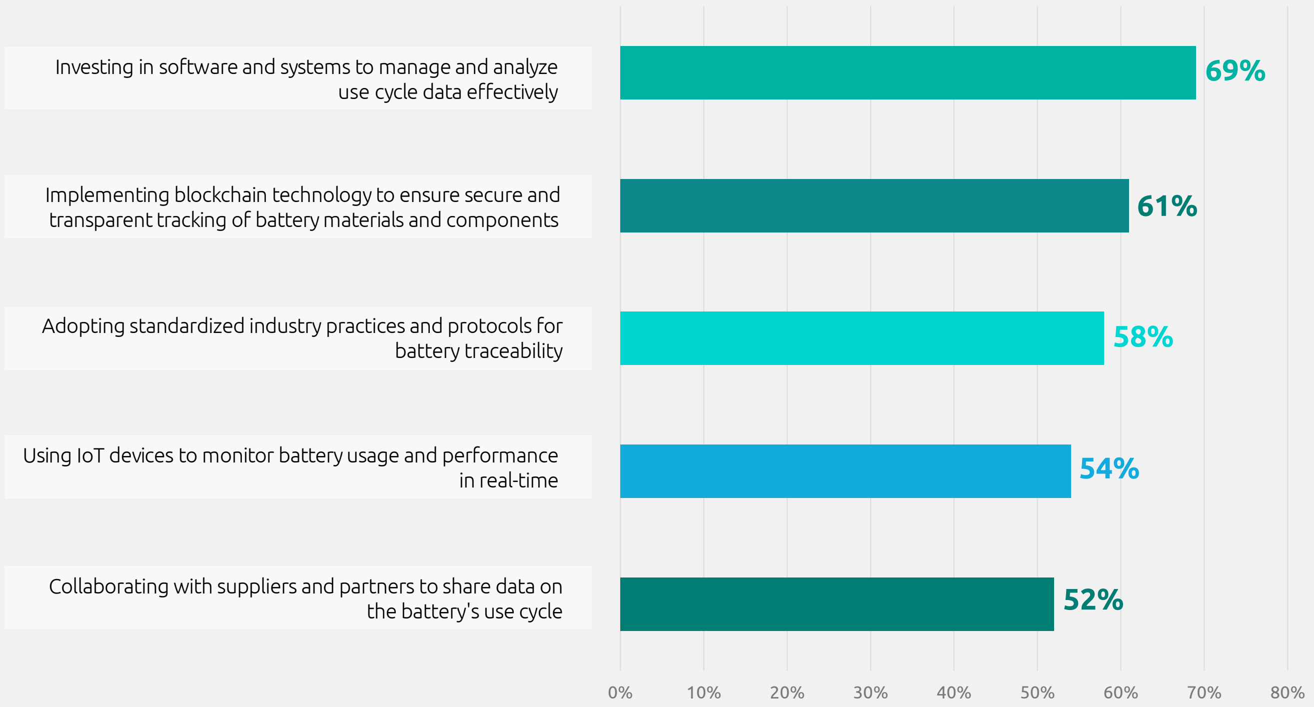
	Battery materials supply / sourcing	Battery manufacturing	Battery integration	Battery usage	Battery second lives & recycling
Strategic opportunities Influencing the direction the company follows	Reinforce / improve and monitor due diligence strategy with field data and information Reinforce / improve & monitor sustainability strategy with field data and information Anticipate / prepare for material scarcity scenarios Enable / secure multi-sourcing strategies for critical materials or intermediary products	Same as for battery materials supply / sourcing adapt battery module purchase strategy to most relevant battery designs compared to OEM needs and value chain control strategy	Optimize CAPEX decisions according to both the vehicle design strategy and the battery modules purchased Reinforce / improve and monitor sustainability strategy with field data and information	Strengthen and develop new revenue streams on the vehicle end-user segment (also true for OEMs with leasing activities) Reinforce / improve and monitor sustainability strategy with field data and information For OEMs with leasing activities – improve operational margin	Generate additional margin through the anticipation of battery ulterior lives scenarios Reduce extended producer responsibility costs For OEMs with recycling activities – improve operational margin Reinforce / improve and monitor sustainability strategy with field data and information
Tactical opportunities Influencing the projects and their management in the company	• Field-data-driven supplier award process • Easier supplier base management Optimized materials or intermediary products acquisition price Data-driven environmental trajectory monitoring and management (scope 3) Accelerated compliance process for other EU regulations (e.g. CSDDD, CSRD)	Same as for battery materials supply / sourcing but for battery modules and intermediary products	Data-driven battery pack design optimization Data-driven manufacturing and integration processes optim. Data-driven environmental trajectory monitoring & mgmt. (scopes 1 & 2) Accelerated compliance process for other EU regulations (e.g. CSRD)	Data-driven user experience offered to vehicle end users (also true for OEMs with leasing activities) Data-driven optimization of battery usage to prolong its life (also true for OEMs with leasing activities) Data-driven environmental trajectory monitoring and management (scope 3) Accelerated compliance process for other EU regulations (e.g., CSRD) For OEMs with leasing activities – optimized fleet management	Data-driven and battery-specific anticipation of its lifecycle scenarios Data-driven environmental trajectory monitoring and management (scope 3) For OEMs with recycling activities – data-driven optimization of battery recycling process Accelerated compliance process for other EU regulations (e.g., CSRD)
Operational opportunities Influencing the day-to-day operations in the company	Time gained for Procurement and Sustainability teams on data and information collection Informed decision-making for Procurement and Sustainability teams	Same as for battery materials supply / sourcing but for battery modules and intermediary products	Time gained for Engineering teams on design activities Time gained for Production teams on manufacturing data collection Time gained for Sustainability teams on activity data collection Enlightened decision-making for Engineering, Prod. and Sustainability teams	Time gained for Sales, Aftersales, Leasing and Sustainability teams on data and information collection Enlightened new business model / new service creation or service improvement for Aftersales and Leasing teams	Time gained for Aftersales, Recycling and Sustainability teams on data and information collection Enlightened decision-making for Aftersales, Recycling and Sustainability teams

★ Enables compliance beyond the EU Battery Regulation ★ Impacts top line positively ★ Enables bottom-line optimization

Building a roadmap for DBP value realization

With so many value-adding use cases to choose from, it can be hard to know where to start. As the figure below shows, a wide variety of approaches are available.

Steps taken to improve battery value chain traceability



*Percentages represent the share of executives currently implement the specified measures to improve traceability.
Source: Capgemini Research Institute, Future of Batteries Survey, September - October 2024, N=751 executives from battery, automotive, energy and utilities.

To create a structured roadmap for value realization, we suggest focusing on three areas:

- Boost supply chain, sourcing, and engineering/R&D
- Augment service offers and improve product performance
- Enable predictive capabilities for second-life and end-of-life asset management

Boost supply chain, sourcing, and engineering/R&D

Better sourcing processes enhancing brand reputation: The DBP improves sourcing and traceability by giving OEMs comprehensive information on battery components and their origin, which makes it possible to track materials all the way through the supply chain. This promotes ethical sourcing methods, increases transparency, and lessens the risk of inadvertently using conflict minerals or unethical labor practices. It helps companies to optimize sourcing strategy and associated costs, and also to anticipate and prepare for materials scarcity scenarios.

Better forecasting and inventory management: Monitoring real-time data on battery manufacturing, delivery, and usage lowers storage costs, avoids stockouts, and boosts supply chain efficiency overall. More than half (53%) of executives cite difficulties in securing a stable supply chain for battery components and materials as an impediment to scaling production.

Better battery design and validation: By analyzing real-world usage data, companies can identify areas for improvement and accelerate the development of next-generation battery technologies and designs, facilitating recycling and disassembly, for example. Improving data flows from cell suppliers to pre-production vehicle test-beds supports comprehensive battery performance validation, reducing the amount of physical testing and the associated costs while accelerating time to market.

> “The battery passport concept will enable suppliers and OEM manufacturers to become increasingly competitive by seeking more sustainable battery properties. It will also empower customers to make informed decisions by considering the complete lifecycle of battery manufacturing and calculating carbon footprint.”
>
> **Mohammed Jerouane, Senior Director, Vehicle Chief Engineer, Powertrain and Battery Integration Testing at VinFast**

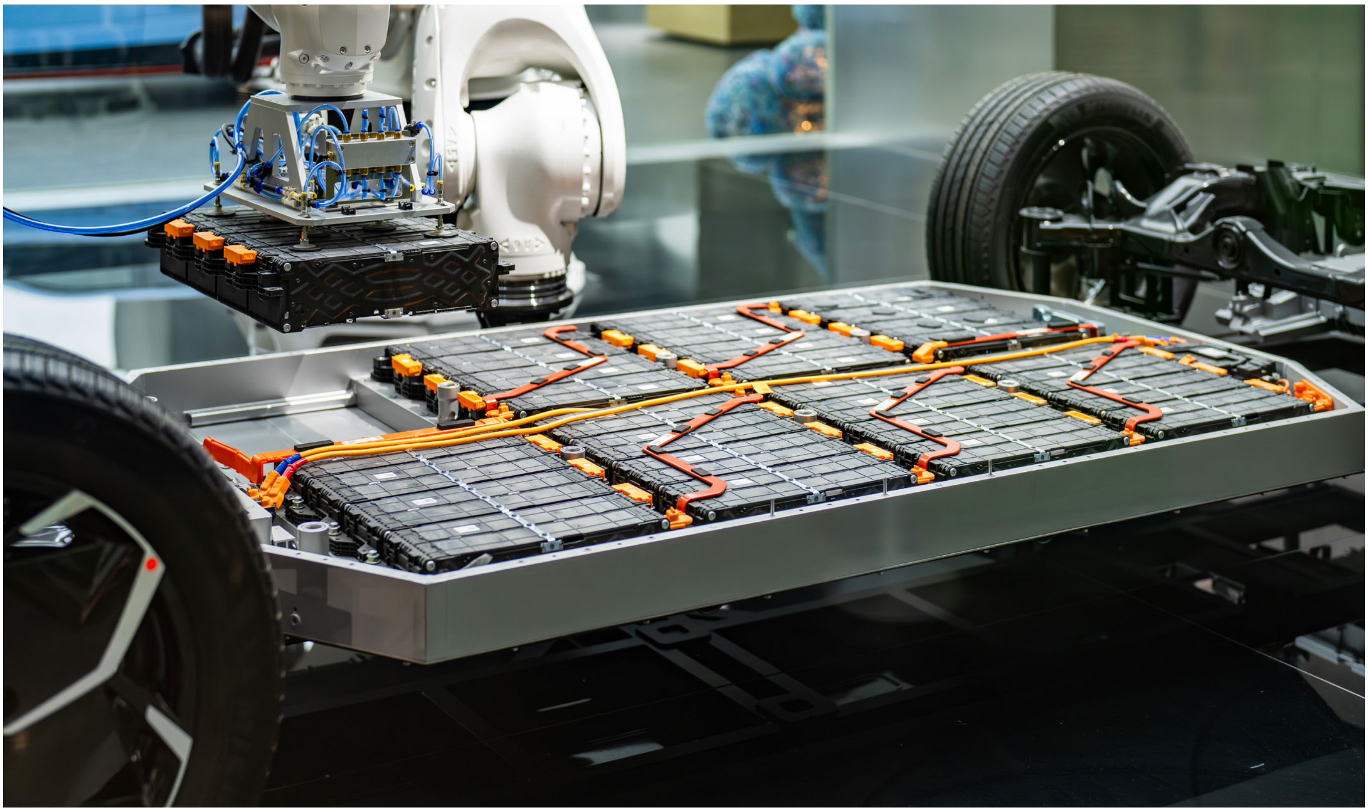
Augment service offers and improve product performance

Enhanced transparency with battery health monitoring: Real-time monitoring of state of health (SoH) and state of charge (SoC) provides a transparent view of battery degradation, and potentially of its financial implications. This data enhances customers’ trust, facilitates fair and accurate valuations in the used car market, and allows proactive maintenance and battery replacement planning. It can also be leveraged to design innovative service offerings, such as battery health subscriptions or guaranteed residual value programs.

Optimized aftersales operations: Analyzing data from multiple vehicles enables robust analysis of the root cause of failure. By identifying failure patterns and clusters, OEMs can proactively address potential issues, reducing warranty costs, minimizing vehicle downtime, and improving customer satisfaction. They can provide or improve predictive maintenance, optimizing service scheduling and reducing the burden on service centers.

Personalized driving experience and energy management: Battery data, combined with data on driver behavior and external factors (e.g. weather and traffic), can be used to optimize energy consumption and personalize the driving experience. Potential features include range prediction, energy-efficient routing, and personalized charging recommendations.

New business models: Around 64% of mobility players are currently exploring battery swapping, with a particular focus on two-wheelers in Asia. Meanwhile, 52% of auto companies are exploring battery as a service to counter EV adoption slowdown amid falling subsidies. DBP data can inform evaluation and implementation of such models.



Automotive manufacturers are exploring models to address infrastructure challenges and cost-effectiveness for EVs

*Percentages represent the share of automotive executives.

Source: Capgemini Research Institute, Future of Batteries Survey, September - October 2024, N=292 automotive executives.

Enable predictive capabilities for second-life and end-of-life asset management

Accurate battery valuation for second-life applications: With dynamic usage data available, OEMs can make better decisions about battery circularity. For example, they can choose the best moment to trigger the move to the next life and ensure that is the most appropriate path.

Easier recycling processes: With access to detailed, up-to-date information on battery composition, waste treatment guidelines, and battery design diagrams, recyclers can increase their efficiency.

What Capgemini can do for you

Capgemini in the battery value chain

Before searching for an off-the-shelf DBP solution, we recommend that economic operators define their priorities in terms of strategic use cases – either compliance-led, added-value-led, or both. A study of this kind will generate efficiencies during PoCs and further digital solution selection processes, while helping the company to organize DBP implementation around clear, structured governance.

Many economic operators wonder if they should build their DBP themselves or outsource the work. We believe a hybrid approach is preferable as it minimizes the need for development from scratch. It does this by leveraging existing infrastructure within the economic operator's IT ecosystem wherever possible, while integrating market-recognized technology solutions to fill any gaps.

For instance, compliance necessitates generating a unique, verifiable identifier associated with a QR code for each battery. If the company has not already implemented a solution for this, it can look for a market solution.

Our service offering around the DBP

Capgemini supports our clients in designing and implementing the strategies and solutions needed not just to operate the DBP, but also to make it into a catalyst for reducing costs and powering value.

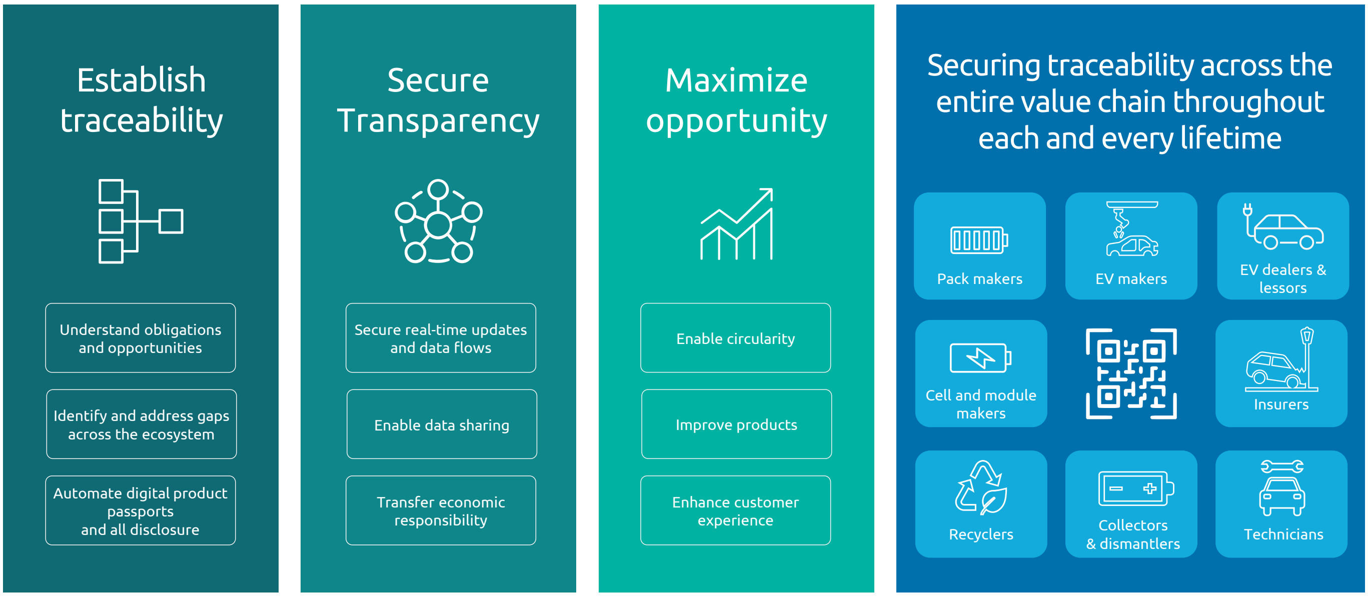
Our Product Traceability for Automotive offer enables clients to:

- **Establish traceability** by going beyond the minimum requirements for static passport data to create efficiency and reduce costs.
- **Secure transparency** by ensuring the data flows seamlessly throughout the product's lifetime to enable value.
- **Maximize opportunity** by leveraging the battery passport to optimize costs, improve products, and enable new business models.

Capgemini can help you at every step of your DBP or product traceability journey, delivering:

- **Connected, interoperable systems:** By enabling a shared semantic model, a unified product identity, and cross-system alignment from PLM to aftermarket, we ensure that a simple button click can satisfy all reporting needs and provide the necessary transparency.
- **Continuous and secure data flows:** Product data can be maintained and updated across usage, service, resale, second life, and recycling – and shared selectively with partners and regulators. Each stakeholder sees only the data that is necessary for them; the battery itself remains secure.
- **Use of compliance data to drive business outcomes:** From ESG disclosures and sourcing decisions to certified re-use, customer transparency, new service offers, and new business models – traceability enables value at every stage.

Our Product Traceability for Automotive framework enables you to go beyond compliance to create value and optimize costs



Conclusion

At Capgemini, we are convinced that the DBP is not just a regulatory constraint but also an enabler of competitive advantage for all battery value chain players.

By leveraging the DBP and integrating it with their existing data infrastructure and expertise, automotive OEMs can unlock significant value across the entire battery lifecycle, from sourcing and design to service and end-of-life management. This will drive innovation, enhance customer satisfaction, and create new business

> “What we want is for the end customer to find an interest in buying an electric vehicle, and as a European battery manufacturer, the battery passport is an advantage. Anything that helps reassure the customer or gives them realistic confidence is a good thing.”
>
> **Alain Raposo – Product and Process R&D EVP at ACC**
> at Paris Motor Show 2024

Definitions

Based on Regulation (EU) 2023/1542 of the European Parliament and of the Council, 12 july 2023

Article 3 – (1) – Battery

Any device delivering electrical energy generated by direct conversion of chemical energy, having internal or external storage, and consisting of one or more non-rechargeable or rechargeable battery cells, modules or of packs of them, and includes a battery that has been subject to preparation for re-use, preparation for repurposing, repurposing or remanufacturing.

Article 3 – (2) – Battery pack

Any set of battery cells or modules that are connected together or encapsulated within an outer casing, to form a complete unit which is not meant to be split up or opened by the end-user.

Article 3 – (3) – Battery module

Any set of battery cells that are connected together or encapsulated within an outer casing to protect the cells against external impact, and which is meant to be used either alone or in combination with other modules.

Article 3 – (4) – Battery cell

The basic functional unit in a battery, composed of electrodes, electrolyte, container, terminals and, if applicable, separators, and containing the active materials the reaction of which generates electrical energy.

Article 3 – (9) – Portable battery

A battery that is sealed, weighs 5 kg or less, is not designed specifically for industrial use and is neither an electric vehicle battery, an LMT battery, nor an SLI battery.

Article 3 – (10) – Portable battery of general use

A portable battery, whether or not rechargeable, that is specifically designed to be interoperable and that has one of the following common formats 4,5 Volts (3R12), button cell, D, C, AA, AAA, AAAA, A23, 9 Volts (PP3).

Article 3 – (11) – Light Means of Transport (LMT) battery

A battery that is sealed, weighs 25 kg or less and is specifically designed to provide electric power for the traction of wheeled vehicles that can be powered by an electric motor alone or by a combination of motor and human power, including type-approved vehicles of category L within the meaning of Regulation (EU) No 168/2013 of the European Parliament and of the Council, and that is not an electric vehicle battery.

Article 3 – (12) – Starting, Lighting and Ignition (SLI) battery

A battery that is specifically designed to supply electric power for starting, lighting, or ignition and that can also be used for auxiliary or backup purposes in vehicles, other means of transport or machinery.

Article 3 – (13) – Industrial battery

A battery that is specifically designed for industrial uses, intended for industrial uses after having been subject to preparation for repurposing or repurposing, or any other battery that weighs more than 5 kg and that is neither an electric vehicle battery, an LMT battery, nor an SLI battery.

Article 3 – (14) – Electric vehicle (EV) battery

A battery that is specifically designed to provide electric power for traction in hybrid or electric vehicles of category L as provided for in Regulation (EU) No 168/2013, that weighs more than 25 kg, or a battery that is specifically designed to provide electric power for traction in hybrid or electric vehicles of categories M, N or O as provided for in Regulation (EU) 2018/858.

Article 3 – (15) – Stationary battery energy storage system

An industrial battery with internal storage that is specifically designed to store from and deliver electric energy to the grid or store for and deliver electric energy to end-users, regardless of where and by whom the battery is being used.

Article 3 – (16) – Placing on the market

The first making available of a battery on the Union market.

Article 3 – (17) – Making available on the market

Any supply of a battery for distribution or use on the Union market in the course of a commercial activity, whether in return for payment or free of charge.

Article 3 – (18) – Putting into service

The first use, for its intended purpose, in the Union, of a battery, without having been previously placed on the market.

Article 3 – (22) – Economic operator

The manufacturer, the authorized representative, the importer, the distributor or the fulfilment service provider or any other natural or legal person who is subject to obligations in relation to the manufacture, preparation for re-use, preparation for repurposing, repurposing or remanufacturing of batteries, the making available or the placing of batteries on the market, including online, or the putting of batteries into service in accordance with this Regulation.

Article 3 – (33) – Manufacturer

Any natural or legal person who manufactures a battery or has a battery designed or manufactured, and markets that battery under its own name or trademark or puts it into service for its own purposes."

NB – Article 38 (11) – "Economic operators that carry out preparation for re-use, preparation for repurposing, repurposing or remanufacturing, and place on the market or put into service a battery that has undergone any of those operations, shall be considered to be manufacturers for the purposes of this Regulation.

Article 3 – (47) – Producer

Any manufacturer, importer or distributor or other natural or legal person that, irrespective of the selling technique used, including by means of distance contracts, either:

- Is established in a Member State and manufactures batteries under its own name or trademark, or has batteries designed or manufactured and supplies them for the first time under its own name or trademark, within the territory of that Member State
- Is established in a Member State and resells within the territory of that Member State, under its own name or trademark, batteries manufactured by others, on which the name or trademark of those other manufacturers does not appear
- Is established in a Member State and supplies for the first time in that Member State on a professional basis, batteries from another Member State or from a third country
- Sells batteries by means of distance contracts directly to end-users, whether or not they are private households, in a Member State, and is established in another Member State or in a third country.

Article 3 – (56) – Waste management operator

Any natural or legal person dealing on a professional basis with the separate collection or treatment of waste batteries.

Article 3 – (58) – Recycler

Any natural or legal person who carries out recycling in a permitted facility.

Article 3 – (64) – Importer

Any natural or legal person established within the Union who places on the market a battery from a third country.

Article 3 – (65) – Distributor

Any natural or legal person in the supply chain, other than the manufacturer or the importer, who makes a battery available on the market.

Additional sources

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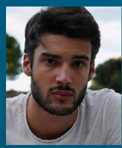

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About Capgemini

Capgemini is a global business and technology transformation partner, helping organizations to accelerate their dual transition to a digital and sustainable world, while creating tangible impact for enterprises and society. It is a responsible and diverse group of 340,000 team members in more than 50 countries. With its strong over 55-year heritage, Capgemini is trusted by its clients to unlock the value of technology to address the entire breadth of their business needs. It delivers end-to-end services and solutions leveraging strengths from strategy and design to engineering, all fueled by its market leading capabilities in AI, generative AI, cloud and data, combined with its deep industry expertise and partner ecosystem. The Group reported 2024 global revenues of €22.1 billion.

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