COMPLIANCE WITH THE EU'S CARBON FOOTPRINT REQUIREMENTS FOR ELECTRIC VEHICLE BATTERIES

An overview of challenges

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SUMMARY

Among the EU Batteries Regulation's key milestones is the introduction of concrete carbon footprint (CF) requirements for all electric vehicle batteries. Representing the first requirements of this kind globally, the rules will evolve in the coming years from mandatory declaration of the battery's CF performance class to a maximum CF threshold that the batteries will need to meet to enter the EU market. These requirements will inevitably create new demands for CF data collection and sharing across global electric vehicle battery value chains.

Drawing on evidence collected though a literature review and interviews with stakeholders from the battery value chain, this CEPS In-Depth Analysis paper provides an overview of prospective challenges to complying with the EU's CF requirements. A first group identifies challenges concerning the collection and quality of CF data. Some issues within this group relate to difficulties- often due to confidentiality concerns- in acquiring certain types of CF data from supply chain actors, as well as confusion due to data submitted in different reference units, challenges in tracking emissions during transportation of end-of-life batteries and limited available data in secondary data sources.

A second group of challenges surround calculating the batteries' CF. Specifically, it was reported that there are practical challenges with defining the functional unit for the CF calculation of the recycling stage, that companies often lack inhouse capacities to perform the CF calculations and that there are disparities between available LCA software.

Actions that can help address these challenges include supply chain initiatives serving as knowledge-sharing hubs that can help break silos across different actors and facilitate data exchange and initiatives to support early availability of secondary data sets before the legal requirements become applicable. Providing further guidance in calculating the CF (e.g. in the form of calculation examples and good practices) can also be helpful for actors who are, in practice, responsible for making the CF calculations.

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INTRODUCTION

Driven by government support, decarbonisation efforts, and technological advancements, electric vehicles (EV) are increasingly infiltrating automotive markets worldwide with the ambition of becoming the dominant types of vehicles on the streets in the coming decades (Albertsen et al., 2021; Barkenbus, 2020). The key battery technologies currently used in EVs and hybrid electric vehicles are lithium-ion, nickel-based and lead-acid (Li et al., 2022) with lithium-ion batteries (LIBs) holding the lion's share of EV applications due to advantages in terms of inter alia high energy density and long-life span (Chen et al., 2022). The use of LIBs in EVs has resulted in rapid growth of their market. According to estimates, the global LIB market has doubled in the past 10 years, from USD 22.5 bn in 2015 to USD 58.6 bn in 2024 (Mohammadi & Saif, 2023).

While battery-powered EVs generally have lower emissions compared to traditional internal combustion engine vehicles especially as we move towards renewable electricity (Fuinhas et al., 2021; Pipitone et al., 2021), EVs still entail significant emissions that need to be addressed (Xia et al., 2023). These emissions are largely linked to the various life cycle stages of the battery source of power, including production, use and recycling (Crenna et al., 2021; Xia et al., 2023). At the battery production stage, emissions are largely attributed to the preparation of battery cathode materials[1] as well as aluminium and electrolytes[2] (Accardo et al., 2021; Li et al., 2022). Emissions also occur during the usage phase and largely depend on the electricity mix and share of renewables, as well as battery performance and longevity (Chen et al., 2022). Finally, the battery recycling process entails emissions which vary depending on the specific recycling technology applied (e.g. pyrometallurgical or hydrometallurgical) (Xia et al., 2023b).

Considering the above, in recent years, political and research attention has shifted from lowering electric battery costs to also making their production sustainable (Ajanovic & Haas, 2019; Fuinhas et al., 2021). This requires developing a thorough picture of the carbon impacts of batteries across their various life cycle stages. Defined as ''the total amount of GHG emissions that come from the production, use, and end-of-life of a product or service'' (Chen et al., 2022, p.2), the carbon footprint (CF) is a key tool that can be used for this purpose and is now required by the recent Batteries Regulation (EU) 2023/1542.

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1 Cathode active materials usually refer to layered metal oxides (some key examples used in LIBs are lithium nickel manganese cobalt oxide (NMC) and lithium nickel cobalt aluminum oxide (NCA)) or polyanionic materials (e.g. lithium iron phosphate (LFP)) (Andreasi Bassi et al., 2023).

2 The electrolytes are substances that physically impregnate the cathode and anode. They allow the transfer of the ion between the anode (negative) and cathode (positive) electrodes (Coffin & Horowitz, 2018; Mekonnen et al., 2016).

Calculating CF has multiple benefits. For regulators, transparency about the CF of batteries provides insights for related policies such as financial support measures or evidence-based CF thresholds that can limit batteries' impact on climate change. This is particularly important as the number of battery innovations are diversifying, with each innovation featuring different CF characteristics. Quantifying the CF of different battery technology solutions can assist policymakers in prioritising support for technologies and processes with lower CF[3]. For companies, mitigating their CF can be a selling feature for their products. Transparency about the CF may also encourage competition among battery makers based on the environmental performance of their products, thereby stimulating innovations (Götz et al., 2022). Furthermore, consumers can also make use of CF information to prioritise products which have lower climate impacts (Peiseler et al., 2023; Peiseler et al., 2022).

At the EU level, the recent Batteries Regulation introduces for the first time concrete CF requirements for batteries. Twelve months after the entry into force of the Delegated Act on the methodology for the calculation and verification of the CF of EV batteries, products entering the EU market will need to be accompanied by a CF declaration that will gradually be linked to a QR code and the digital battery passport. Starting in 2026, the CF requirements will become stricter. This will begin with a mandatory declaration on the CF performance class of the battery and will eventually lead to a maximum CF threshold that will need to be met by the batteries to enter the EU market (Rizos & Urban, 2024a).

The new EU regulatory framework for batteries, which poses new CF requirements, is expected to have an impact on global battery value chains (Rizos and Urban, 2024a; Fang, 2023). However, there are several complexities involved in calculating the CF of batteries that have been documented. These issues mostly arise from the production process of batteries, which involves the assembly of various components at different locations. A variety of data would therefore need to be collected from several supply chain actors which also brings forward verification challenges (Fang, 2023; Xia et al., 2023b).

Inspired by the upcoming CF requirements of the EU Batteries Regulation, this paper delves into the challenges of calculating the batteries' CF and implementing the relevant obligations for companies introducing batteries in the EU market. It is based on insights

3 Technology-wise, for example, Lithium Iron Phosphate cathodes can be larger and heavier than Nickel-Manganese-Cobalt cathodes, but also offer superior cycle life and safety. Beyond liquid electrolyte LIB, other technologies like all-solid-state batteries can have higher energy density and cell safety (Peiseler et al., 2023). Process-wise, the concept of 'Gigafactories' presents potential for reduction of CF during battery production phase, thanks to process innovations such as water-based cathode slurry mixing (Shunmugasundaram et al., 2022), direct dry coating (Schumm & Kaskel, 2023), or lower scrap rate during lithium-ion battery production (Turetskyy et al., 2021).

from the BATRAW EU-funded project[4] that implements circularity models for LIBs, and perspectives from stakeholders from the battery value chain. The LCA work in BATRAW is conducted by the LEITAT Technological Centre.

The paper is structured as follows: section 1 presents CF regulatory approaches in the EU and beyond, while section 2 documents related challenges in the literature. Section 3 presents challenges to implementing the CF requirements as identified by companies in the BATRAW project and other stakeholders. Section 4 is devoted to some policy messages.

4 During its 4-year course the BATRAW (Recycling of end-of-life battery packs for domestic raw material supply chains and enhanced circular economy) project will apply reuse and recycling processes for LIBs and will also implement a digital battery passport.

1. Carbon footprint regulatory approaches

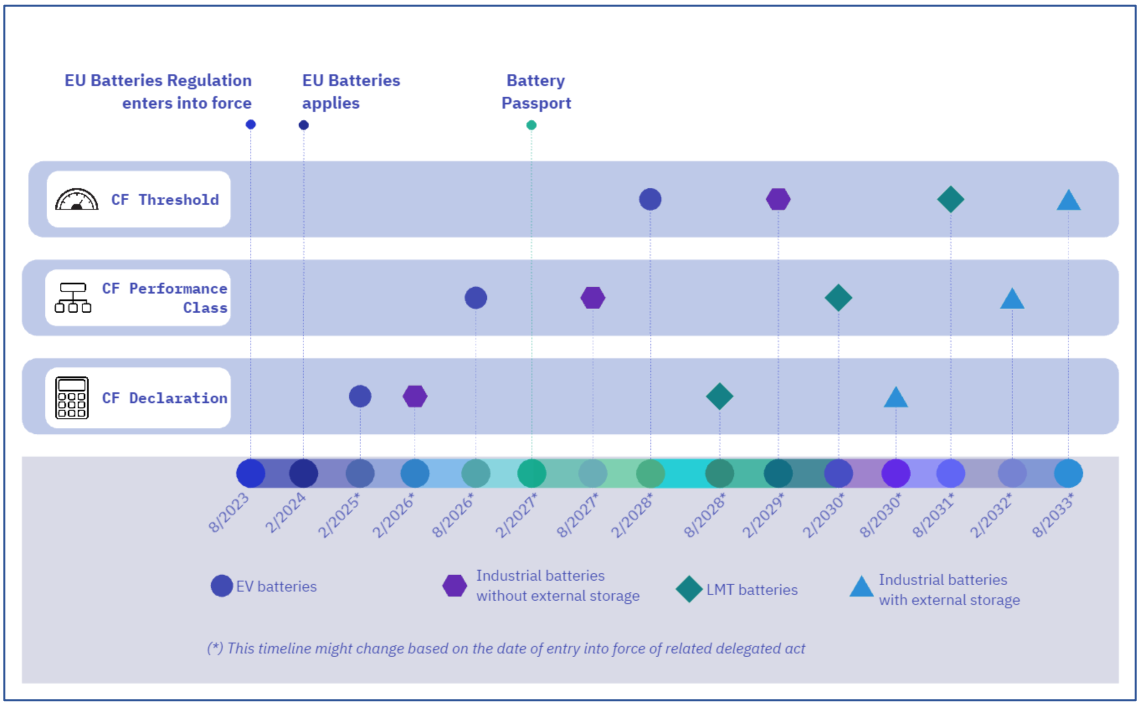
The EU Batteries Regulation (EU) 2023/1542 entered into force on 17 August 2023, replacing Battery Directive 2006/66/EC. The objective is to ensure the internal market functions efficiently while also addressing the impact that batteries and waste batteries have on the environment and human health. The Batteries Regulation lays down requirements around four main areas. First, it sets rules for traceability and transparency across the battery life cycle. Second, it stipulates sustainability requirements, notably regarding the CF of batteries. Third, it features rules on the circularity of critical raw materials, including targets for collection, recycling, material recovery and the use of recycled materials in manufacturing new batteries. Fourth, it establishes requirements on the performance and longevity of batteries.

In addition to portable, automotive and industrial batteries, the Batteries Regulation expands its scope to cover EV batteries. It applies to batteries marketed or put in service in the EU, whether they are produced in the EU or not. The EU Batteries Regulation is a key achievement of the European Green Deal and the Circular Economy Action Plan.

Among others, Article 7 is one of the prime novelties of the Batteries Regulation. It sets out the timeline for the declaration, performance classification and threshold on the CF[5] of several types of batteries. Information on the CF of batteries will become part of the Battery Passport. The Batteries Regulation presents a staged application: the declaration of CF will apply first, followed by the classification of CF performance and finally compliance with CF thresholds to enter the EU market. It also mandates different timelines for different battery types. Electric vehicle batteries will be the first category to be governed, followed by industrial batteries without external storage, light means of transport (LMT) batteries and industrial batteries with external storage (Figure 1).

5 At the time of writing of the paper, a delegated act on the methodology for the calculation and verification of the CF of electric vehicle batteries was under preparation in line with Article 7 of the Batteries Regulation. The technical basis for the methodology was provided by a report by the Joint Research Centre (JRC) on rules for the calculation of the CF of EV batteries (see Andreasi Bassi et al., 2023). Building on the European Commission's Environmental Footprint (EF) method and the Product Environmental Footprint Category Rules for Batteries (PEFCR), the report proposes the methodology for calculating and verifying the CF of EV batteries.

Figure 1 Timeline of the EU's rules on carbon footprint of batteries



Source: Author's elaboration on the EU Batteries Regulation.

The application of the Batteries Regulation makes batteries the first product in the EU to be governed by rules on the CF and digital battery passports (Haupt et al., 2024). The Batteries Regulation is also the first tool to govern the market access of batteries based on CF threshold (Melin et al., 2021; Peiseler et al., 2022). The EU Batteries Regulation is to date the most comprehensive regulatory initiative on the CF of batteries globally. As discussed below, there are also initiatives in other parts of the world on the CF of batteries, although the measures adopted seem to be less explicit, especially regarding the declaration, performance class requirements and threshold of the CF of batteries.

At the national level, the French ecologic bonus programme for electric vehicles is a complementary measure to the EU Batteries Regulation. It provides criteria for the government's financial aid for buyers of electric vehicles based on the environmental score of the vehicles. More specifically, the programme establishes a carbon footprint threshold for electric vehicles to be eligible for the ecologic bonus, ranging from EUR 900 to EUR 8 000 depending on the vehicle type. Before 2023, the calculation of the environmental score was only based on the CF during the use phase of vehicles, but since 2024, it has included the production phase. A new decree was published, introducing the calculation method of the environmental score and the minimum score required to be eligible for the ecological bonus for new electric passenger cars. The programme therefore aims at incentivising low-carbon production of electric vehicle components, notably batteries.

At the international level, the Global Battery Alliance (GBA) provides a rulebook on the calculation of GHG of LIBs for EVs. The GBA Greenhouse Gas rulebook was first published in October 2022, and is a pivotal document in standardising the calculation of the battery CF at global level. The rulebook underwent a stakeholder consultation, the results of which contributed to the revision of the rulebook in November 2023 (see GBA, 2023). While the rulebook itself is not a regulatory tool, it provides valuable sources of technical references for governments worldwide to set harmonised rules for calculating and verifying the CF of EV batteries.

An interesting example of a CF-related initiative adopted by a government internationally is Japan's Carbon Footprint of Products (CFP) Programme. The programme provides guidelines for calculating and labelling the CF of products and is managed by the Japan Environmental Management Association for Industry (JEMAI). The list includes a wide range of products, however, only small secondary batteries and industrial lead batteries are listed when it comes to batteries. Nevertheless, the programme also offers the possibility for new product categories to be included, provided that the applicants develop their own CF calculation method and submit it for third party verification. If the CF calculation result passes the verification, the company can obtain a CFP mark in its product. Participation in the programme is voluntary.

2. CHALLENGES DOCUMENTED IN THE LITERATURE

The novelty of the Batteries Regulation makes it difficult to fully anticipate and assess issues related to its implementation, particularly when it comes to newly introduced instruments like the CF calculation and declaration. This section provides a first account of prospective challenges as identified in the present literature.

Data availability and data quality

Ensuring access to quality data is instrumental in accurately calculating the CF of electric batteries. However, as documented by different studies, obtaining high-quality data from different actors across the battery supply chain to enable CF calculations can be a challenging task. The global nature of the battery supply chains exacerbates the difficulties in accessing and verifying CF data.

Collecting *primary data* (i.e. company-specific data) could face several challenges. A study by Haupt et al. (2024) assesses the feasibility of collecting primary data mandated by the EU Batteries Regulation and finds that the CF declaration of comprehensive collection of data related to anodes, cathodes and other battery components might encounter both technical and economic challenges. The complexity of the battery supply chain and data secrecy make it difficult to access the data required for the CF calculation (Peiseler et al., 2022).

Additionally, many companies consider data on environmental indicators to be highly sensitive and critical. Some data might reveal a company-specific production process, which contributes to their market value (Haupt et al., 2024; Xia et al., 2023). In this respect, CF declarants might refuse to grant the 'notified body' of the Batteries Regulation access to primary data due to secret industrial know-how (CEA & BRGM, 2023). This challenge becomes even greater when CF declarants are not able to provide the required data themselves but need to obtain them from their suppliers (Tsougka, 2024).

Authors also point to the difficulties in obtaining the *secondary data* necessary for CF calculation. The search and selection might require notable knowledge and effort (Haupt et al. 2024), while stakeholders often rely on some secondary data sources facing certain limitations. For example, the Life Cycle Data Network (LCDN) – the European Commission's LCA data set – is still missing some data on the production of several battery raw materials[6]. Additionally, certain data on the LCDN recycling process do not fully represent contemporary or possible future recycling processes; consequently, these data may quickly become outdated. More importantly, some of the data in the LCDN bear

6 Such as nickel compounds, cobalt compounds, battery-grade graphite, lithium carbonates and hydroxides or battery precursor.

potential risks of imprecise estimation or underestimation of the CF of the production of some battery materials. This might incentivise companies to resort to secondary data to obtain lower CF results, rather than relying on their primary data. Addressing the issue of underestimating the CF values for primary raw materials in the LCDN, as well improving the completeness of the LCDN data sets are among the recommendations of the assessment by CEA and BRGM (2023).

Another documented challenge concerns the verification of CF data, notably the risk of non-accurate CF declaration by companies and loopholes in the verification processes carried out by competent authorities. Several scenarios would favour the above circumstances. It has been argued that there may be cases where battery manufacturers who cannot provide complete CF data or have a higher CF than the threshold, may declare non-accurate CF values to get their batteries approved in the EU market. Public authorities (called 'notifying authorities' (Article 22) in the Batteries Regulation) might not have enough resources to supervise all the CF declarations of individual companies.

To address the challenges mentioned above, several measures have been proposed. These include establishing a rigid punishment mechanism for false CF declaration and ensuring that sufficient resources are allocated to public authorities to verify the accuracy of CF data (Xia et al., 2023).

Carbon footprint calculation methodology

While the final methodology for calculating the CF of batteries has not yet been published[7], the results of the public consultation[8] of the draft delegated act provide a first picture of the stakeholders' views and prospective concerns. While some stakeholders express support for the proposed rules, some raise issues around the lack of clarity in the methodology and the presence of unreasonable elements or potential biases in the calculation.

Several comments revolve around the functional unit with stakeholders arguing that the use of the battery's warranty years as the years of operation might distort the CF calculation. Stakeholders also share concerns about the rules related to the system boundary. For example, the methodology does not cover the transport of the battery to recyclers, which also may represent a considerable part of the life cycle when it comes to emissions. Regarding CF data, several stakeholders raise concerns that the proposed text of the Delegated Act does not incentivise economic operators to provide company-

7 At the time of writing this paper, the delegated act on the methodology for the calculation and verification of the CF of electric vehicle batteries was discussed at the political level.

8 The consultation was highly engaged, with 127 stakeholders providing their feedback in written form. They represent companies and business (41%), business associations (18%), academic and research institutions (8%), NGOs (6%), as well as public authorities, consumers and the citizens.

specific data for a certain process (e.g. data for nickel production). Data security is also a shared concern, with some stakeholders calling for the notified body to be the only competent body to access and aggregate companies' confidential data.

Electricity modelling is another contentious topic, in which some stakeholders advocate for clearer definition of key points in electricity modelling[9], or consideration to include off-site Power Purchase Agreements (PPAs) in the methodology under certain conditions. Commentators also point to issues concerning the economic allocation rules, particularly when comparing processes in different countries. Some stakeholders emphasise that the rules on calculating the CF of the batteries end-of-life management and recycling present some potential limitations and recommend the use of a cut-off method instead of the Circular Footprint Formula method. Finally, several stakeholders point to the need for better visualisation of several elements of the rules, a Guide-To for the industry including examples of calculations, and best practices of CF reports.

Capacity issues

Compliance with the CF rules can pose both technical and economic challenges for economic operators. Technically, the calculation of the CF is a relatively novel field, and requires comprehensive expertise in the battery supply chain and an understanding of the LCA methodology. It also requires companies to ensure that their digital infrastructure, such as software, allows for (semi-) automatic calculations. In addition, small and medium-sized companies may face difficulties when collecting some of the necessary data due to their limited capacities and capabilities (Haupt et al., 2024).

There is also an economic concern related to the cost of testing required to obtain CF data. For example, to validate data about the estimated lifetime of batteries, companies would need to do cycle tests. This activity is costly as it requires companies to provide a representative sample of cells to ensure the robustness of the estimates. Testing cost can increase if one considers that even moderate modification to the battery design will require another round of testing. This challenge becomes greater for new and small producers of EVs, potentially hindering innovation (Peiseler et al., 2022).

Threshold compliance

When it comes to setting the threshold for the CF of EV batteries, it has been argued that it would need to strike a balance between meeting the EU's climate ambitions and the feasibility for companies to comply with the capped emission level. Battery manufacturers and their upstream suppliers would need to innovate their activities to lower their CF However, these adjustments to production facilities will take time (EUROBAT, 2021). If the

9 Such as the definition of directly connected electricity and national average electricity consumption mix.

threshold is not sensible, there is a risk that part of the battery production would move out of the EU, e.g. to countries where the battery supply chain generates a higher CF and it is more difficult to verify CF data (Fang, 2023; Morfeldt et al., 2023). For these reasons, it has been suggested that the decision on the threshold would require close communication between EU regulators and private players, so that it is based on up-to-date information about the industry's practices as well as adapted to different battery technologies to reduce the CF (EUROBAT, 2021; Peiseler et al., 2022).

3. CHALLENGES IDENTIFIED THROUGH STAKEHOLDER INTERVIEW CONSULTATION

This section presents challenges linked to the CF requirements of the EU Batteries Regulation as identified through an interview consultation with companies across the battery value chain implementing pilots for calculating the CF, researchers and NGOs.

3.1. METHODOLOGY

For this study, we follow an exploratory research approach relying on qualitative data collected from stakeholders. Indeed, such an approach is appropriate for collecting perspectives on under-researched topics (Stebbins, 2001). So far there is limited evidence on how the CF requirements would affect those companies introducing batteries in the EU market since the EU Batteries Regulation has only recently been adopted. To collect views and evidence in a qualitative form, we conducted in-depth interviews[10] with companies implementing pilot CF calculations as well as with other stakeholders. For this we assembled a sample of nine stakeholders utilising our networks[11] in this domain including the partners involved in the BATRAW project. Table 1 shows the list of interviewed stakeholders.

Table 1. Overview of stakeholders featured in the sample

No.	Activities	Position of interviewees
1	Technological Centre	Researcher
2	Automobile manufacturer	Head of Sustainability
3	Research institute	Research Associate
4	Non-profit association	Manager
5	Automobile manufacturer	Policy Specialist
6	Automobile manufacturer and battery cell producer	Head of Environment
7	Automobile manufacturer and battery cell producer	LCA Specialist

10 Interviews lasted between 45 and 60 minutes and took place between April and July 2024 except for one interview that was conducted in December 2022 in the context of an assessment of the EU battery passport (see Rizos and Urban, 2024a) and also featured perspectives on the carbon footprint requirements.

11 Building a sample based on our knowledge and network on a topic is described in qualitative research as purposeful sampling technique (see Saunders et al., 2009) .

8	Industry association	Manager
9	Provider of supply chain traceability and circularity services	Co-founder

Source: Author's own elaboration.

The discussions during the interviews were based on a semi-structured questionnaire (see Annex I) that was sent to the experts prior to the interview[12]. For each interview we then prepared a detailed write-up transcript, ending up with 40 pages of transcripts in total. To facilitate the analysis, data were then coded – with each code describing in a short text a challenge raised in the interviews (Saldaña, 2013) – and then transferred to an excel document.

3.2. Challenges

Carbon footprint data collection and quality

A prime challenge that was brought forward during several interviews with companies and researchers concerns the difficulties in acquiring certain data for calculating the batteries' CF. Corroborating previous insights from the literature review, experts from the automotive industry held that it is often challenging to convince their suppliers to share certain types of data, while in some cases the suppliers would not share the details of the methodology they use for their calculations. In the latter case, the actor responsible for introducing the battery in the market would need to make certain assumptions, for example about how much energy and what kind of energy is consumed in the production of a battery module or pack. Regarding the latter, it was argued that while there are standardised methodologies in the EU for calculating the residual energy mix, this may not be the case globally which brings forward further uncertainties linked to how the CF of particular materials or components is calculated.

The experts also emphasised the international dimension of supply chain data with most battery component suppliers operating outside the EU. Since they are not placing their product on the EU market, they are not directly affected by the Batteries Regulation and will thus need to be convinced by the companies doing business in the EU to provide high-quality data. Additionally, as noted by interviewees, the supply chain visibility of companies responsible for placing the battery on the market often does not extend too far upstream, thus meaning that the process of creating better visibility will take some time. Using the example of cell manufacturing, one expert from a company sourcing cells noted that it is difficult for them to trace emission generation in stages earlier than cell

12 Interviews were conducted in an online format and were recorded with the consent of the interviewee.

manufacturing. Moreover, even for this stage they sometimes have difficulties understanding the emissions calculation method used by their supplier and which material and energy inputs have specifically been considered in the calculations.

Confidentiality concerns are a key factor for companies hesitating to share CF data. As also observed for other categories of battery-related data that will need to be collected to comply with the requirements of the Batteries Regulation (see Rizos & Urban, 2024a, 2024b), there is still a long way to go to develop a common perception across supply chains of the importance of sharing data for improved transparency. However, in cases where suppliers do share data, they sometimes do not disclose the full account of how they ended up with these values – again due to confidentiality concerns – which complicates verification of these values. Although some interviewees have observed that the Batteries Regulation is starting to have an impact, changing the mindset of companies and longstanding business practices regarding data sharing cannot occur overnight.

Collection of CF data also faces quality challenges as shown by existing pilots including BATRAW. Data are often submitted by suppliers in different reference units which means that the company or researcher making the overall CF calculations would need to transform them in the same unit, a process that can be time consuming. Data quality is sometimes low since suppliers make assumptions for the data they submit, which may not reflect reality or may omit mentioning certain parameters when submitting the data. As a result, it may be required to rely on secondary sources to fill certain gaps or cross-validate with literature sources and available databases[13] if the data represent realistic values. As noted by some experts, it is important for the actor making the CF calculations to have engineering capacities to assess the quality of data and apply weights for different values to produce meaningful range values. Another related challenge concerns the timing of data collection for long-term projects such as those funded by the EU's research and innovation programmes. Specifically, for such projects data collection may take place during the early stages of the project and towards the end they may not reflect the current situation in terms of the grid, the technology used etc. This may create issues for projects that need to report data and calculations towards the end of their duration.

As also observed in BATRAW, one particular phase facing data issues is transportation of end-of-life batteries. Although the companies make efforts to track emissions that depend on the type of vehicle making the transportation and the emission levels, in practice it is difficult to trace all the steps involved in the shipping process. Given that making an

13 According to interviewed auto manufacturers, to validate their calculations they often rely on the IMDS (International Material Data System) which has been developed by the industry.

accurate calculation of the CF in every step is challenging, it is often necessary to use average value and make certain assumptions.

As discussed earlier, companies may resort to secondary sources of data to fill data gaps where the rules give this flexibility, though some potential issues were raised regarding their use. First, secondary sources such as databases also have data gaps[14] and thus in the end it may be necessary to use proxies for certain values. Furthermore, some interviewees argued that secondary sources may provide overly optimistic values, so it is important to prioritise the identification of primary CF data to meet the requirements of the Batteries Regulation. Concerns were also raised that some companies may opt to use average values from secondary sources if they think that these values would help provide a better CF performance than primary data. Finally, it was stated that there are differences between the data sets available in different available databases which may affect CF calculations.

Carbon footprint calculation challenges

Moving to the CF calculation stage, some challenges brought up during the interviews concerned the definition of the functional unit. In one case experts mentioned that while the draft delegated act establishing the carbon footprint methodology may be convenient for assessing the impact of one battery, in the particular case of BATRAW, whose aim is to perform the calculations for the process of recycling big quantities of waste batteries that come in different models, lifespans, chemistries and capacities, and go beyond this quantification[15], that functional unit is not suitable. As a result, they needed to research the literature, which offers several alternative approaches, to determine a suitable unit of measurement for the recycling phase.

In addition, in the experts' assessment, the CF calculations will be more complex for heavy-duty vehicles than for light-duty vehicles (such as EV cars). Specifically, the experts observed that while EV cars often have few models of battery configuration, heavy-duty vehicles in the market have various system configurations to adapt to different usages. For example, trucks and buses could have up to 6 or 7 batteries, and the number and configuration of battery packs in the vehicles affect the durability of the battery e.g. how many charge cycles it endures. Therefore, it is more difficult to connect battery packs with the usage of the vehicles, which depends on the needs of the vehicle users. This in turn complicates the CF calculations for heavy-duty vehicles.

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14 As an example, the interviewees mentioned that specific solvents or chemicals are often missing in the available databases.

15 The researchers specifically aimed to compare the recycling process implemented in the BATRAW project with conventional recycling processes as well as quantify the environmental savings of obtaining recovered materials via recycling EV batteries compared to obtaining them through mining.

The experts were also cautious about not giving the possibility to companies to use Power Purchase Agreements (PPAs) in the CF methodology. Specifically, the draft delegated act foresees using only the national average energy mix or the directly connected electricity between the place of generation and the place of use of electricity in the calculation methodology. Experts perceived that this approach would demotivate companies that are investing in PPAs for renewable energy as they would not benefit from this investment.

Another issue concerned the companies' expertise in LCA analysis. The level of capacity in this domain is not homogeneous across companies. While some have been increasingly investing resources to gain in-house expertise on LCA and develop digital solutions e.g. blockchain-based tracking of supply chain emissions, others – including both EU companies and those based in third countries – are still facing a lack of knowledge in this area. The interviewed experts further brought attention to the economic costs and expertise (including IT systems) required for continuously tracking the batteries' CF. Given that that there are continuous changes in the suppliers of materials and components, material composition, location of materials etc., the companies would need to incorporate these new developments and frequently recalculate[16] the CF which can be a costly process.

While there are several free and paid CF calculation tools available for calculating CF[17], some experts believe that they pose difficulties in their usage. The tools need to provide at least two functions: gathering all the data sets at one single points and processing them to calculate the CF. However, some tools were not specifically designed for CF calculation and thus need to be revised to include this functionality. There are other tools that are better suited for CF calculations, but they are not available for free and come with a cost. Additionally, experts pointed to the lack of harmonisation between the available LCA software; it has been observed that different tools might generate different CF results even if they use the same data inputs. There is a need for verification and standardisation to ensure the preciseness and comparability of CF values by different tools.

Table 2 provides a summary of the key challenges related to the CF requirements of the Batteries Regulation as identified during the experts' consultation.

16 As of November 2024, the draft delegated act establishing the carbon footprint methodology requires a new calculation of the batteries' CF where the amount of CO2-equivalent emissions increases by more than 10% which according to interviewed experts will be challenging. In the experts' view, this is due to the difficulty in tracking when the 10% threshold is reached because even small changes (e.g. in suppliers, materials composition, the production location) can lead to changes in CF.

17 Some examples include IMDS which was developed by automobile manufacturers and Catena-X which has published a Product Carbon Footprint Rulebook.

Table 2. Key challenges to calculating the carbon footprint (CF) of batteries

List of challenges
• Difficulties in acquiring certain types of CF data from suppliers of battery components and materials • Lack of clarity regarding the methodologies used by suppliers for calculating certain CF values • Limited supply chain visibility upstream creating difficulties to collect or verify data • Reluctance by supply chain actors to share CF data due to confidentiality concerns • CF data quality challenges due to data submitted in different reference units • Challenging to track emissions during the transportation phase of end-of-life batteries • Limitations of secondary data sources in terms of availability and quality of available data • Difficult to define the functional unit for the CF calculation of the recycling stage • Practically challenging to calculate the CF of heavy-duty vehicles with various battery configurations • Limited in-house expertise for LCA and calculation of batteries' CF • Disparities between available LCA software

Source: Author's own elaboration.

4. Policy messages

With a new regulation focusing on batteries and waste batteries, the EU is gearing up its efforts to reduce the environmental impacts linked to batteries' value chain. Among its various sustainability and transparency requirements, the Batteries Regulation aims to introduce a robust framework for the CF of batteries with gradually tightening requirements. Starting with a CF declaration that will need to accompany each battery entering the EU market, the rules will lead to the setting of a CF threshold that will govern the access of batteries to the EU market. These rules will in turn lead to new requirements for collecting and analysing CF data from different regions within global battery value chains.

Existing pilot cases of calculating the CF of batteries to meet the new regulatory requirements provide some lessons for prospective challenges. Like other categories of primary data that will need to be collected in the context of the Batteries Regulation, it will require some time for supply chains to mature and different players to understand the importance of sharing good-quality data. During this transition period, and as has also been recommended for other categories of data in the digital battery passport (see Rizos & Urban, 2024a), **supply chain initiatives and platforms serving as knowledge-sharing hubs can help break existing silos across different actors and facilitate data exchange**. **They could also act as channels for raising awareness about the CF calculation method**.

In addition to primary data from companies, secondary sources of data are expected to play a role in the CF calculation of batteries – where their use is allowed by the Batteries Regulation – especially since retrieving primary data for all CF categories will not be easy in practice. In this context, **early availability of secondary data sets before the legal requirements become applicable would enable stakeholders to assess the data quality, select suitable datasets and identify potential data gaps**. Initiatives such as the upcoming EU-wide environmental footprint data sets EF 4.0 (successor of the EF 3.1) can help enhance reliability, consistency and comparability of data.

The complexities in calculating the CF point to the need for further guidance in this domain especially in areas where existing pilot cases reveal calculation uncertainties (e.g. during the recycling or transportation stages). The availability of calculation examples and good practices – also in the context of knowledge-sharing initiatives as discussed above – can help experts who perform the calculations in practice understand how to handle data from various suppliers and overcome challenges (e.g. data collected in different reference units or incomplete collected data sets).

5. ANNEXES

Annex I: Questionnaire used for the interview consultation

1) What actions are you undertaking to calculate the carbon footprint of electric vehicle batteries?
2) What types of carbon footprint data are you currently collecting?
3) How do you assess the provision of the Battery Regulation to introduce carbon footprint threshold for batteries entering the EU market? Do you foresee any implementation challenges and if yes how do you think they could be addressed?
4) Can you specify any specific categories of data that are very difficult to calculate or obtain from supply chain partners, company-specific data or secondary datasets?
5) Do you foresee any challenges in the calculation methods for the carbon footprint?
6) Are there any specific actions that can be taken to support companies in calculating the carbon footprint requirements?

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ABOUT THE BATRAW PROJECT

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

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