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Strategic (Re)Design of Devices with Portable Batteries - Adapting to Upcoming European Union Battery and Waste Battery Regulation

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The European Union's new battery regulation aims to improve sustainability, safety, and create a circular economy for all member states. This regulation brings therefore major changes and challenges to the (re)design of electronic devices with batteries, especially in ensuring that batteries are removable and replaceable. The aim of this research is to set out a methodology on how to deal with these changes and challenges. To explore this in a practical way, a design case study was carried out. This case study helped to understand the regulation and the implementation for other electronic devices. Consequently, this case was used to develop the Ecomply Methodology (EM). The EM provides practical and easy-to-use tools to ensure that battery-powered devices meet the regulation. The EM is intended to support decision-making in three types of users, i.e., designers, management, and external agencies or manufacturers.

Regulatory compliance; Removable and Replaceable Batteries; Waste Battery; Compliance Methodology

1. Introduction

Batteries play a crucial role in powering the devices we interact with regularly. Think of your smartphones or maybe even your electric vehicle. In 2030, the global demand for batteries is expected to increase fourteen times compared to 2019, and this increased use of batteries brings some issues [1]. That is why the European Union (EU) adopted a new battery and battery waste regulation. The main goal of this regulation is to increase sustainability and safety during the complete lifecycle of batteries and to create a circular economy for all EU member states [1]. However, this regulation brings major changes and challenges to the (re)design of electronic devices with batteries, especially in ensuring that batteries are removable and replaceable.

The aim of this research is to set out how to deal with these changes and challenges in (re)developing electronic products to comply with this regulation. This aim is summarised in the following research question:

How to strategically (re)design devices with portable batteries according to upcoming regulation regarding batteries and waste batteries?

2. Overall structure

To address the research question, the study was carried out in three phases. Phase I involved conducting comprehensive research, beginning with the analysis of the battery and waste battery regulation. The research gradually builds up the information needed for the design and development phases of both the case study and methodology. Phase I concludes with a list of requirements.

In Phase II, a design case study was conducted to explore the research question in a practical way. A powerbank was chosen for this design case, as it represents a battery-powered device in its most fundamental form. Phase II thus covers the full design and development process of the powerbank.

The design case helped to understand the regulatory requirements and the implementation for other electronic devices. Consequently, the design case was used to design and develop a methodology to ensure strategic compliance for battery-powered electronic devices. This was done in phase III and resulted in the Ecomply Methodology (EM), which provides practical and easy-to-use tools to ensure that battery-powered devices meet the regulatory requirements. The EM is intended to support decision-making in three types of users, i.e., product designers, management boards, and external agencies or manufacturers. This research paper mainly focuses on this third phase.

3. Background

A comprehensive discussion of the entire background exceeds the scope of this research; therefore, only the key highlights are presented.

3.1 The upcoming regulation

The primary motivation for this research is the upcoming regulation regarding batteries and waste batteries. Consequently, the research starts by setting out the fourteen chapters of the regulation in detail. Based on this, it will be possible to determine additional relevant topics for the research, which can then be researched further.

Chapter I outlines the subject matter, scope, objectives, and definitions. The battery types relevant to this research are portable batteries and portable batteries of general use, which are defined in Chapter I as follows:

Portable battery: *A sealed battery that weighs 5 kg or less, is not designed specifically for industrial use and is neither an electric vehicle battery (EV battery), a light means of transport battery (LMT battery), nor a starting, lighting and ignition battery (SLI battery)* [2].

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* [2].

Chapter II starts with the restrictions on materials used in batteries. Besides, it includes Article 11 in which the removability and replaceability of portable batteries are discussed. The requirements outlined in this article are vital to the design and development of battery-powered consumer products and thus the methodology. The article states that the entire battery, no individual cells or other parts, must be removable from the electronic device. This should be possible using commercially available tools or provided free specialised tools. Additionally, clear instructions and safety information on using, removing, and replacing the battery should be provided, along with the product and online [2].

Chapter III lays down the requirements for labelling batteries. It is important to note that batteries should be purchased conform with existing regulations rather than being developed from scratch. Therefore, the remaining chapters exceed the scope of this research and are not discussed further, as they are primarily relevant to battery development rather than the design and development of battery-powered devices.

3.2 Batteries

The regulation and case study are centred around batteries and thus this subject needed extra research. In terms of battery shapes, pouch cells are strongly discouraged due to safety and coin cells are unsuitable due to their low capacity, the options are therefore limited to cylindrical or prismatic cells [3] [4]. This cylindrical or prismatic should have a detachable connection to the electronic device, to keep it removable and replaceable.

The circuit board should provide all the necessary functionalities for the electronic device. However, the specific details and design of the circuit board are beyond the scope of this research. Note that the USB charging cable should be of type C and should have the newest power delivery fast charging technique [5].

3.3 Stakeholder analysis

Stakeholders for this research are anyone related to the design and development of battery-powered devices, the methodology, or related to the regulation of batteries and waste batteries. Additionally, the research was conducted in collaboration with a company in the promotional sector, making this stakeholder the most influential and powerful in shaping both the design case and the methodology.

4. Design and development of the methodology

The developed methodology is named the Ecomply Methodology. Its primary focus is on ensuring to **comply** with battery and waste battery regulation. Besides, it provides additional tips for creating more **eco**-friendly products, i.e., guidelines that contribute to a better circular economy. Lastly, the methodology is designed for **electronic** products.

4.1. Goal of the methodology

The goal of the methodology is to support designers, the company purchase department and manufacturers in the development of consumer products in compliance with the upcoming regulation. In other words, it will be used to redesign and select electronic products with batteries to ensure compliance with the regulation on batteries and waste batteries. To increase accessibility, the methodology should be written in English, so all stakeholders understand the toolbox well. In addition to supporting product (re)designs for regulatory compliance, a second goal is to transfer other relevant information for redesigning electronic products obtained during the case study (outside of the regulation). As it would be a pity for this information to be lost.

4.2 Current methodology

The company does not have prescriptions for the design process of its products. Instead, the in-house designs are based on the expertise of the designer and product manager. The decision-making process is mainly based on experience and gut feeling.

However, a big part of the designs in the company collection are not produced in-house. Many of the products in the company collection are manufactured by factories in countries like China. This is a faster, easier, and cheaper option.

Open designs are used for this, which are designs where the makers allow for free and permitted use and modification by anyone. For these open designs, the current process starts with researching within the product group and browsing for inspiration, gathering various ideas, discussing them, and finally selecting one to proceed with.

However, the lack of a methodology emphasises the need for one. A methodology for design and development namely enhances the performance of designers by contributing to the structuring of actions and thoughts [6]. Furthermore, methodologies are highly effective and efficient in routine scenarios due to the possibility of a rapid process [6]. Improvements could thus be made by having at least some design methodology.

It was found that complex and time-consuming methodologies are often the reason they are not used in companies [7] [8]. This fits in with the thought of going from no concrete methodology to a complex methodology has less chance of success. Therefore, an easy-to-use and easy-to-implement methodology should be developed.

4.3 Users of the methodology

The methodology could be used in three different types of stakeholders and use cases. The primary users of the methodology could be product designers within or outside the company. This means that these users already have experience in designing, and the methodology should support their (re)design process.

Secondary users of the methodology could be the company (purchase) management. As the decision-makers responsible for, e.g., purchasing choices or design choices, they could benefit from the methodology since it should support and enhance their decision-making process.

As said, it could be faster, easier and cheaper not to design the products in-house. Therefore, tertiary users of the methodology could be agencies and manufacturers in, e.g., China. They could also benefit from the methodology as a more open source of information used in selecting open designs.

4.4 Literature review and design for X

There exist many design methodologies available for use across all engineering and design disciplines without a golden standard [9] [10]. These methodologies often exist in multiple adaptations and iterations, leading to many variations [9] [10]. Since a huge number of methodologies already exist, there is no need to reinvent the wheel. It is thus best to find an existing methodology that aligns with the goals of the Ecomply Methodology (EM), fits well within the company and alter this methodology where needed. Using an existing methodology as a basis will save time and effort and ensure reliability, as the methodology has already been researched and tested in the literature.

However, due to the high number of existing methodologies available, it is impractical and too much to discuss many of them in detail. Therefore, only the most suitable existing methodology will be discussed, while, in fact, extensive research has taken place.

The most suitable existing methodology is the Design for X (DFX) methodology, where 'X' represents compliance. This fits the goals of the EM, the current situation and suits the primary goal of (re)design for compliance. Why DFX is most suitable will be discussed in the next section.

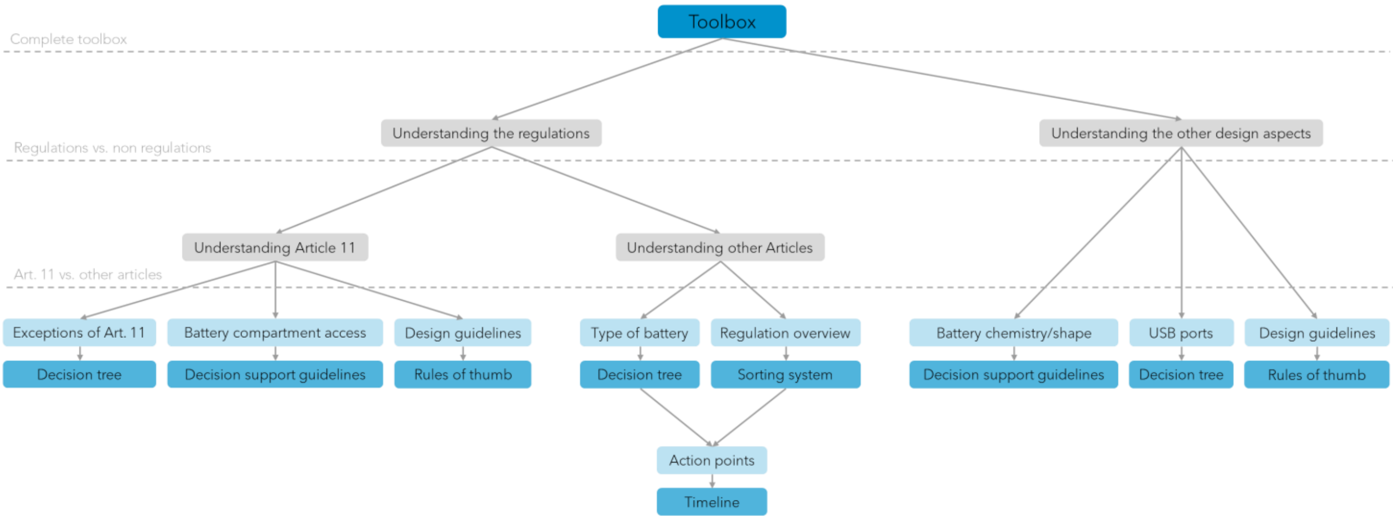


Figure 1.; Methodology structure.

4.5 Research gap and proposed Ecomply Methodology

Design for X (DFX) is a design methodology that emphasises a limited number of design tools (typically 7 ± 2), enabling focused optimisation [11]. Most DFX methodologies do not make design decisions but instead evaluate them from specific perspectives. These tools should be familiar to users or easy to learn. The DFX methodology comprises thus a toolbox that includes systematic procedures, knowledge bases, and logical worksheets, avoiding the need for expensive data collection or processes. DFX is thus highly practical, and the balance is aimed between creativity and guidance and between structure and freedom. Lastly, the tools are integrative and consistent within the product development process [11]. This aligns seamlessly with the current and Ecomply Methodology (EM) goals.

In terms of 'X', there are many possibilities, such as design for cost, assembly or maintenance. Since the goal of the EM is compliance, it would be logical to search for Design for Compliance methodologies. However, 'X is compliance' appeared to be a gap in the literature. A search yielded a minimal result of only six relevant papers on design for compliance. These papers mainly show the gap rather than filling it.

The main conclusion is thus the lack of practical support for dealing with the new batteries and waste batteries regulation. This should be avoided in the Ecomply Methodology (EM). That is why, for the EM, a toolbox with practical tools, as described in DFX, was designed.

5. Methodology structure

The structure of the EM is divided into regulation related and non-regulation related tools, see Figure 1. The regulation-related tools are further subdivided, specifically focusing on Article 11 (regarding the removability and replaceability of batteries) and other relevant articles. For the scope of this research, there is merely focused on regulation-related tools.

5.1 Exceptions Article 11

Not all products with portable batteries are required to comply with Article 11. In other words, certain batteries do not need to be removable or replaceable by the end user; instead, they may only need to be by professionals or, in some cases, may not require removal or replacement at all. To provide a clear understanding of when a battery must be removable and replaceable, a decision tree has been established to optimally guide the determination of exceptions. A part of this decision tree can be found in Figure 2.

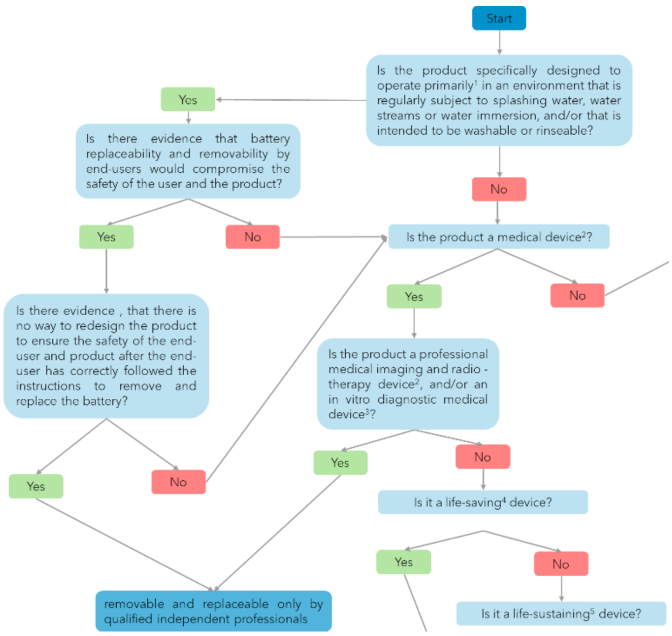


Figure 2.; Part of decision tree tool for exceptions Article 11.

5.2 Battery compartment access

To facilitate the removal and replacement of batteries according to Article 11, the battery compartment must be designed to be opened. Currently, many products that are required to meet Article 11 do not have accessible battery compartments. To address this issue, a set of decision support guidelines for redesigning the battery compartment mechanism has been created. These guidelines support decision-making rather than giving one solution for all situations, as no universal battery compartment access solution exists. Following the decision support ensures a more efficient, logical, and streamlined redesign process. Note that the mechanism should fit the existing product, rather than adjusting the product to suit the mechanism. This avoids unnecessary further redesign, which avoids unnecessary changes to the manufacturing process and reduces cost and (redesign) time. To ensure confidentiality, the battery compartment access guide has not been included.

5.3 Design guidelines

Design guidelines were set up to ensure that batteries are readily removable and replaceable by the end users at any time during the product's lifetime. Those are subdivided into five subcategories:

- Tools
- Instructions and safety information
- Spare parts
- Software
- Optimising removability and replaceability

These guidelines help to facilitate the redesign of electronic products to ensure compliance with Article 11. These design guidelines have also been excluded to ensure confidentiality.

5.4 Type of battery

To fully understand the regulation, it is crucial to identify the specific type of battery in question, as different battery types come with varying requirements. To simplify this identifying process, a decision tree has been created, which helps to determine the type of battery you're dealing with and can be seen in Figure 3.

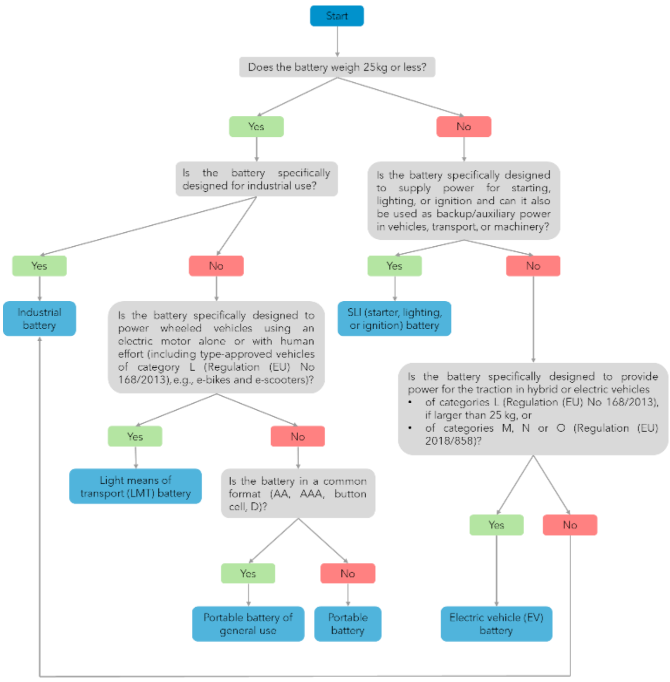


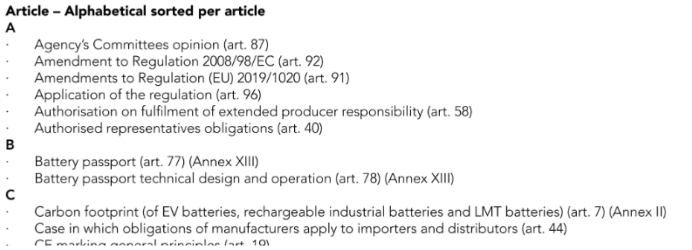
Figure 3.; Decision tree tool for type of battery.

5.5 Regulation overview

Regulation can often feel overwhelming, particularly when searching only for a specific section or subject. To simplify this process, the regulation has been organised based on the key information. This structured approach allows for easier identification of relevant information, making it more accessible and manageable to navigate. The parameters used for this structuring are:

- Articles – Chronological sorted per chapter
- Articles – Chronological sorted per article
- Annex – Chronological sorted per annex
- Articles – Alphabetical sorted per chapter
- Articles – Alphabetical sorted per article
- Annex – Alphabetical sorted per annex

A small part of this sorting system can be found in Figure 4. It should be noted that page numbers are not provided, as they vary depending on the language of the regulation.


Article – Alphabetical sorted per article

A
- Agency's Committees opinion (art. 87)
- Amendment to Regulation 2008/98/EC (art. 92)
- Amendments to Regulation (EU) 2019/1020 (art. 91)
- Application of the regulation (art. 96)
- Authorisation on fulfilment of extended producer responsibility (art. 58)
- Authorised representatives obligations (art. 40)

B
- Battery passport (art. 77) (Annex XIII)
- Battery passport technical design and operation (art. 78) (Annex XIII)

C
- Carbon footprint (of EV batteries, rechargeable industrial batteries and LMT batteries) (art. 7) (Annex II)
- Case in which obligations of manufacturers apply to importers and distributors (art. 44)

Figure 4.; Part of the sorting system for regulation overview.

5.6 Action points

The articles of the regulation do not all enter into force simultaneously, which can make it confusing and overwhelming to track what becomes applicable and when. To address this, key action points have been summarised in a timeline, providing a clear overview of the implementation schedule. A small part of this timeline can be found in Figure 5.

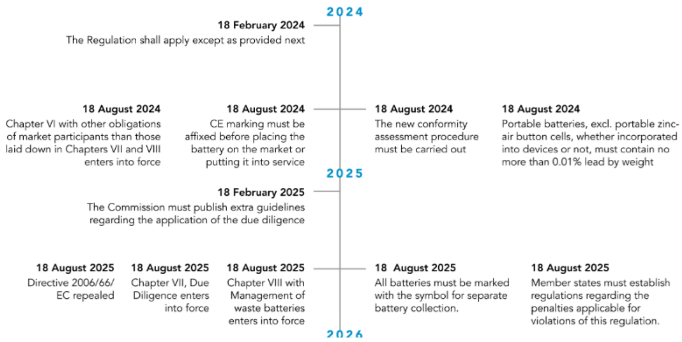


Figure 5.; Part of the timeline for action points.

6. How should the toolbox be used?

There is no mandatory order for using the tool but following the recommended structure will help to ensure optimal results. This order is addressed in this section.

For understanding Article 11, start by determining whether your product must comply with Article 11. The developed decision tree can help with this assessment (see 'Exceptions Article 11'). If compliance with Article 11 is required, redesign the product as needed while using the battery compartment access tool (see Battery Compartment Access'). Additionally, other relevant design aspects from Article 11 should be implemented using the provided guidelines (see 'Design guidelines').

For understanding the other articles start with identifying the type of battery in your product, as different battery types have distinct requirements (see 'Type of battery'). Then, review the regulation overview to get a comprehensive understanding of the additional requirements for the specific battery type in your product (see 'Regulation overview'). After understanding the battery type and regulation, use the timeline to plan and schedule the necessary actions to ensure compliance (see 'Action points').

7. Design case study

A design case study was carried out to explore the regulation in a practical way. This design case helped to understand the regulation and the implementation for other electronic devices. Consequently, this case was used to develop the Ecomply

Methodology (EM). The content of the design case could not be discussed due to confidentiality.

To evaluate the EM, a fictitious earbud casing redesigning was performed. Throughout this redesign process, the designer's actions were observed - whether she searched for specific features and how she interacted with the tool. To enhance the evaluation, the designer was asked to think out loud, providing more insights into her thinking process. This evaluation revealed only minor issues, such as typos, misalignments and some difficulty navigating through the menu layout. Interestingly, once the homepage was reviewed, the overall structure quickly became clear and intuitive. These issues were corrected and with that, the EM is finished.

8. Discussion

While this research presents the Ecomply Methodology (EM) for redesigning electronic devices with batteries, several limitations need to be considered. First, the scope of the research is focused on portable batteries and portable batteries of general use. However, the EM does not distinguish between these two battery types, which could limit the EM's effectiveness. General-use batteries are often already removable and replaceable and might have different design and regulatory requirements. Lastly, users could interact differently with each battery type, resulting in less effective and efficient (re)design.

Second, the intended goal is that the EM applies to all electronic devices with batteries (of general use). However, since the design case is limited to powerbanks, it remains uncertain whether the EM will be effective for all electronic products. The EM could be improved by adding more design case studies that illustrate the redesign process in various product categories, not just powerbanks.

Lastly, while the EM focuses on the design aspects of electronic products, it may lack in organisational compliance. A product might thus be compliant, but the company also needs to follow regulatory requirements, e.g., act due diligence. Because design is the main focus, the EM could lack full organisational compliance. A more comprehensive methodology for also the organisational aspects is advised.

The primary academic contribution of this research lies in the development of the Ecomply Methodology (EM). The EM fills a literature gap regarding design-based legal compliance. Unlike existing methodologies, the EM is highly practical. Lastly, and of great significance, the EM is scalable across different electronic products, broadening its application and usefulness. The research also presents an example of a structured approach for managing (new) regulations in product development. This gives valuable insights into how regulations and their requirements can be integrated into the design process. More specifically, this research provides a perspective on how removability and replaceability requirements, as outlined in Article 11 of the regulation, can be structurally addressed within the design process, serving as an example that many could follow.

9. Conclusion

To strategically (re)design devices with portable batteries in compliance with the battery regulation, particularly Article 11, this research provides a methodology, the Ecomply Methodology (EM). Article 11 mandates that portable batteries should be easily replaceable and removable by the end user, presenting a design challenge. Through extensive research and a comprehensive powerbank design case study, the research develops the strategic EM to help designers and manufacturers navigate through the regulatory landscape effectively. The research conducted, and the outcomes offer valuable insights for both the company and the broader electronics industry.

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