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# The role of standards in support of material efficiency requirements under the Ecodesign Directive

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ABSTRACT

Material efficiency is a new field within the Ecodesign Directive. To support its implementation, standardisation mandate M/543 was issued with the aim of developing generic material efficiency standards for ecodesign. This article investigates how the standards developed under M/543 can support the implementation of material efficiency under the Ecodesign Directive and the potential challenges of this process. As a result of M/543, nine standards were published; two of these can be applied directly, while seven are horizontal and provide the framework for developing product-specific standards. The study showed that M/543 and its associated standards have already played a key role in supporting material efficiency by creating a shared understanding and definition of various aspects of material efficiency. The standards provide a baseline from which relevant aspect(s) of material efficiency can be selected, and thus ensure a level playing field and alignment in the understanding of material efficiency across product groups. However, the actual use of the standards shows significant variance in how they are applied, potentially hindering continuity in the development of standardisation. Therefore, clear guidelines on the use of the standards should be established.

## 1. Introduction

The circular economy is increasingly recognised as a key approach to decouple growth from resource use, thereby mitigating waste problems and resource constraints and reducing environmental pressure (Ellen MacArthur Foundation, 2014). As a result, the circular economy has been high on the European Commission's agenda since the publication of the first Circular Economy Action Plan (CEAP) in 2015. In the CEAP, a circular economy is defined as an economy "*where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized*" (European Commission, 2015a, p. 2). The proposed actions in the first CEAP were strongly linked to the existing European regulatory framework, primarily focusing on removing regulatory barriers and creating regulatory requirements and incentives to support a circular economy, taking the existing regulations as the starting point.

In spring 2020, the European Commission published the second CEAP (European Commission, 2020a). This updated CEAP proposed initiatives to establish "*a strong and coherent product policy framework that will make sustainable products, services, and business models the* norm *and transform consumption patterns so that no waste is produced in the first place*" (European Commission, 2020,p. 5). One of these is the Sustainable Products Policy Legislative Initiative. As part of this initiative, the Commission proposed a regulation establishing a framework for ecodesign requirements for sustainable products (ESPR) and repealing the Ecodesign Directive in March 2022 (European Commission, 2022a). With this proposal, the scope is expanded to nearly all products, and there is an improved focus on circularity compared to the Ecodesign Directive as the new regulation specifies that requirements should be set up within areas such as product durability and reliability; product reusability; and product upgradability, reparability, maintenance, and refurbishment (European Commission, 2022a). This could hugely increase the regulation's future impact.

Until the new regulation is adopted and comes into force, however, the Ecodesign Directive continues to play a key role in the transition to a circular economy, as described in both the first and second CEAP (European Commission, 2020a; European Commission, 2020d). The aim of the Ecodesign Directive is to continuously improve the environmental performance of energy-related products by setting mandatory minimum requirements for their design, thereby removing the environmentally worst performing products from the European market (European Commission, 2009). The Ecodesign Directive is a framework directive,

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within which product-specific ecodesign requirements are laid down in implementing measures or voluntary agreements. At the beginning of 2022, the Ecodesign Directive covered 30 product categories through 27 implementing measures (European Commission, 2022b) and three voluntary agreements (European Commission, 2022c).

The Ecodesign Directive is part of the so-called New Approach, under which harmonised standards are used to show compliance with regulations and thereby provide access to the European market (Maitre-Ekern et al., 2018). Harmonised standards are European standards developed by a recognised European Standardisation Organisation, which have been referenced in the Official Journal of the European Union. They are used to specify which measurement methods should be used to show compliance with the ecodesign requirements specified in the implementing measures (Toulouse, 2014). If no harmonised standards exist when the implementing measures come into force, transitional methods can be used until harmonised standards become available (European Commission, 2016).

One of the specific actions in the first CEAP was a request to European standardisation organisations to develop standards on material efficiency aspects that could support such requirements in the ecodesign implementing measures (European Commission, 2015a). This resulted in the issuing of a new standardisation mandate, M/543, on material efficiency. A standardisation mandate or standardisation request is a request from the European Commission for specific actions from the European Standardisation Organisations. The purpose of this mandate was to develop generic standards for ecodesign requirements related to material efficiency, covering aspects such as recyclability, recoverability, reusability, durability, reversible disassembly, and end-of-life extraction time for energy-related products. These standards were published in 2019 and 2020; see Table 4. However, no official procedure exists explaining how to use the developed standards in the ecodesign process, and while there are indications as to how they could be used and the first experiences are being made, it remains to fully understand the role of the new standards in supporting the uptake of new material efficiency requirements in the Ecodesign Directive. The research question is thus:

How can the standards developed under M/543 support the implementation of material efficiency requirements under the Ecodesign Directive, and what potential challenges does this process present?

This article contributes to the existing literature by adopting a qualitative approach to understanding the standards development process and identifying its associated potential challenges and opportunities. The article examines how the potential future application of these standards will be achieved and what role they can play in supporting future material efficiency requirements under the Ecodesign Directive. The article focuses solely on the process in the European Committee for Standardisation (CEN) and the European Committee for Electrotechnical Standardisation (CENELEC) and is thus not concerned with the standardisation process undertaken by the European Telecommunications Standards institute (ETSI).

## 2. Literature review

The Ecodesign Directive was, in its early years, criticised for its singular focus on energy efficiency in the use phase (Huulgaard et al., 2013; van Rossem and Dalhammar, 2010). This was partly due to its original scope, namely energy-using products. The Directive has, however, been effective in improving the energy efficiency of both energy-using and energy-related products (Centre for Strategy and Evaluation Services and Directorate-General for Enterprise and industry, 2014; Egenhofer et al., 2018), which underlines its huge potential for improving material efficiency aspects as well.

A significant barrier to the increased adoption of the material efficiency requirements outlined in the implementing measures is the lack of standards that can be used to show compliance with the new material efficiency requirements (Bundgaard et al., 2017; Tecchio et al., 2017). Furthermore, Mathieux et al. (2014) emphasise the importance of having standardised methods for determining the extraction time for components when targeting the recyclability of products through product policies. Other studies have argued that it is feasible economically and technically to verify material efficiency requirements through the development of refined methods (ECOS, 2018).

The journey of the Ecodesign Directive from focusing mainly on energy efficiency to increasingly focusing on material efficiency has already taken more than 10 years. It largely began in 2009, with the scientific research programme "Resource Efficiency Assessment of Products" (REAPro) (Mathieux et al., 2020) The first comprehensive material efficiency requirements were not adopted until 2019 (Mathieux et al., 2020). These included the availability of spare parts, maximum delivery time for spare parts, design for disassembly, access to repair and maintenance information, statements on the content of critical raw materials (CRM), provision of the latest available firmware, and the availability of secure data deletion ((3) European Commission, 2019).

So far, only a few studies have investigated the impact and role of the new standards. In two studies, based on their experiences of developing the implementing measures for enterprise servers and the REAPro programme, Peiró et al. (2020) and Mathieux et al. (2020) highlight several factors contributing to successful implementation of material efficiency requirements. One of these was the development of the material efficiency requirements based on standardised methods, underlining the importance of the timely development of the standards (Mathieux et al., 2020; Peiró et al., 2020). Another study focusing on the application of EN 45554 *General Methods for the Assessment of the Ability to Repair, Reuse and Upgrade Energy-related Products* acknowledges the standardisation efforts that have taken place to date, but concludes that efforts are still needed to adapt the existing assessment methods to different product groups (Matarin et al., 2022). Along the same lines, Schischke et al. (2022) discuss the pros and cons of applying horizontal standards compared to product-specific standards through a study of mobile phones and tablets. While these studies do provide some insights, it remains to be analysed what potential challenges and opportunities exist within the process of developing standards to support the implementation of material efficiency requirements under the Ecodesign Directive.

## 3. Methods

To investigate the process of developing standards pertaining to M/543, a qualitative approach is imperative, and interviews with key persons in the process comprise the main methodology applied in this research.

### 3.1. Semi-structured interviews with actors involved in standardisation mandate M/543

Nine interviews were conducted with key actors involved in standardisation mandate M/543. The interviewees represent each of the different types of organisations involved in the standardisation process, and include key actors such as the chairpersons of several working groups and committees. At the request of some interviewees, and to enable the interviewees to answer the questions freely, the interviews are anonymised. An overview is provided in Table 1.

The purpose of the interviews was to examine the process of developing the standards as well as the limitations and potential of these standards to support the implementation of ecodesign requirements for material efficiency under the Ecodesign Directive. The interviewees were selected based on snowball sampling (Bryman, 2012). One of the authors is involved in M/543 and, based on this involvement, a key actor heavily involved in M/543 was identified. This actor was interviewed and helped to identify other key actors. These key actors were then contacted and interviewed. After each interview, the interviewee was asked to identify other key actors relevant to the research. This process continued until no new insights were provided. Alongside the snowball

**Table 1**
Overview of interviewees.

| Interviewee | Involvement | Representation in this study |
|---|---|---|
| No 1 | Chairperson of Joint Technical Committee 10 (JTC10)<br>Involved in the process of developing M/543 and involved in all working groups developing the standards | Industry representative |
| No 2 | Chairperson of a national mirror committee on the environment and circular economy | Former representative of a standardisation organisation, currently industry representative |
| No 3 | An active member of working groups 3, 5 and 6; also familiar with the process of the other three working groups | Industry representative |
| No 4 | Participated in working groups 4, 5 and 6 | Public authority representative |
| No 5 | Chairperson for CENELEC TC111x and chairperson for a national mirror committee<br>Participated in all working groups | Industry representative and representative of a standardisation organisation |
| No 6 | From 2018, convenor of working group CEN-CLC/TC 10/WG 3 | NGO representative |
| No 7 | No information on involvement in specific working groups | Representative of a standardisation organisation |
| No 8 | Involved in working groups 5 and 6. | European Commission representative |
| No 9 | Involved in the development of M/543<br>Member of JTC10<br>Participated in all working groups | Industry representative |

approach, it was also a priority to have a wide representation of actors in the study.

The research interviews were semi-structured (Bryman, 2012). Each was based primarily on the same interview guide with only small variations depending on the specific interviewee. The semi-structured format ensured that the same topics were covered in all interviews, while still providing the possibility for the interviewees to cover other relevant topics in relation to the research theme. All interviews were conducted using Skype or telephone and lasted between 45 and 60 min. The interviews were recorded and subsequently transcribed. Following transcription, they were coded in NVivo, a qualitative data analysis computer program, using 26 different themes, including actor involvement, the role of different actors, reparability, refurbishment, and the resulting standards.

### *3.2. The document review of the current use praxis of the EN 4555X series of standards*

To examine the current use praxis of the EN 4555x series of standards, a review was conducted of documents concerning the use of the standards for servers and data storage products as well as for mobile phones, smartphones, and tablets. The documents included in the review are listed in Table 2.

**Table 2**
Overview of documents covered by the review.

| Topic | Document covered |
|---|---|
| Servers and data storage products | The implementing measures covering servers and data storage products ((3) European Commission, 2019).<br>Standardisation mandate M/573 (European Commission, 2021a). |
| Mobile phones, smartphones and tablets | Preparatory study covering mobile phones, smartphones and tablets (European Commission et al., 2021). |

## 4. Standardisation mandate M/543 on material efficiency

This section describes the process of developing standardisation mandate M/543 and the standards under M/543, hereafter referred to as the EN 4555X series of standards. The process is described here in order to analyse the challenges involved in these processes.

### *4.1. Developing the standardisation mandate*

The starting point for the standardisation mandate was provided in the annex to the 2015 CEAP. Here, one of the actions to support a circular economy was "*a request to European standardisation organisations to develop standards on material efficiency for setting future Ecodesign requirements on durability, reparability and recyclability of product*s" (European Commission, 2015b: 2). This resulted in standardisation mandate M/529 (European Commission, 2015c). However, this mandate was rejected due to the wording of some of the key concepts that the standards should cover (Interviewee #1, 2019). A negotiation process then began between the Commission and the European Standardisation organisations, and agreement was reached on the new standardisation mandate M/543 on material efficiency, which was adopted in December 2015 (Interviewee #5, 2019).

This redefinition of M/529 to M/543 took almost a year and involved the development of a shared understanding of the key concepts related to material efficiency between the industry, NGOs, and the Commission (Interviewee #1, 2019; Interviewee #9, 2020). The purpose of the reformulated mandate M/543 was to develop standards that could support the implementation of material efficiency in the implementing measures under the Ecodesign Directive by specifying parameters to be evaluated and calculation and test methods (European Commission, 2015d). The standards needed to be generic and support later product-specific standards in relation to the specific regulation established in the implementing measures (European Commission, 2015d).

M/543 on material efficiency emphasised three main aspects which the standardisation mandate should focus on: (1) extending product lifetimes; (2) the ability to reuse components or recycled materials from products at end-of-life; and (3) the use of reused components and/or recycled material in products (European Commission, 2015d).

### *4.2. The standards development process*

#### *4.2.1. The organisation of the work under M/543*

One of the first steps was to organise the standardisation work under CEN and CENELEC. Therefore, the Technical Boards of CEN and CENELEC established a joint CEN-CENELEC Technical Committee 10 (JTC10) called "Energy-related Products – Material Efficiency Aspects for Ecodesign". The work was organised under a joint technical committee because the standards needed to cover both electrical and non-electrical products.

#### *4.2.2. The work programme*

After M/543 was accepted by CEN, CENELEC and ETSI, the three standardisation organisations developed the work programme, which was finalised in June 2016. ETSI, CEN and CENELEC were assigned different work tasks in the work programme. However, the following analysis of the process of developing the standards will take its point of departure in the work conducted by CEN and CENELEC. The work programme for CEN and CENELEC included the publication of two technical reports and the development of ten standards (CEN and CENELEC, 2017a). The standards were required to develop general assessment methods for assessing (1) durability, (2) upgradability, (3) repair, (4) reuse, (5) remanufacture, (6) recyclability and recoverability, (7) reuse of components, (8) proportion of recycled material content, (9) declaring the use of critical raw materials (CRM) and (10) providing

information relating to material efficiency aspects (CEN and CENELEC, 2017a). The two technical reports provide a guide on how to use generic material efficiency standards when writing product-specific standards as well as definitions related to material efficiency. The work programme was revised several times during the process. The main changes were the cancellation of the technical report on how to use generic material efficiency standards when writing energy-related product-specific standardisation deliverables and the merging of the standards on upgradability, reuse and repair into one standard (CEN and CENELEC, 2020, 2019, 2018, 2017b). Furthermore, the deadlines were extended for most standards and technical reports (CEN and CENELEC, 2020, 2019, 2018, 2017b).

#### 4.2.3. The working groups

The actual standardisation work began with a kick-off meeting of JTC10 in September 2016. The work on developing the specific standards and technical reports was then taken up in six working groups; see Tables 3 and 5 (CEN and CENELEC, 2020, 2019, 2018, 2017b). These working groups were composed of experts and observers representing different organisations, as outlined in Table 4 (CEN and CENELEC, 2020, 2019, 2018, 2017b). The experts met on a regular basis to develop the standards and technical reports and, later in the process, implement comments received following the circulation of drafts (CEN and CENELEC, 2020, 2019, 2018, 2017b). The working groups also received a large number of comments when the standards and technical reports were sent for secretary enquiry (CEN and CENELEC, 2020, 2019, 2018, 2017b).

### 4.3. The resulting standards

Five years after M/543 was adopted, all nine standards were published. The EN 4555X series of standards vary in their level of the maturity of the developed assessment methods, corresponding to the complexity of the topic under development. Two of the standards can be applied directly, namely EN 45558:2019 on CRMs and EN 45559:2019 on methods for providing information relating to material efficiency aspects. All other standards are horizontal, providing the framework for developing product- or product-group-specific standards. For details on the standards and technical reports developed under M/543, see Table 5.

**Table 3**
Overview of the working groups, the number of experts, observers and meetings (CEN and CENELEC, 2020).

| Working group | Experts | Observers | Meetings |
|---|---|---|---|
| WG 1: Terminology | 50 | 17 | Unknown |
| WG 2: Durability | 85 | 20 | 10 physical meetings<br>16 web meetings |
| WG 3: Ability to repair, reuse and upgrade energy-related products | 104 | 20 | 17 physical meetings<br>5 web meetings |
| WG 4: Ability to remanufacture and methods for determining the proportion of reused components in energy-related products | 54 | 17 | 19 meetings |
| WG 5: Ability to recycle and recover energy-related products, recycled material content of energy-related products | 85 | 20 | 10 physical meetings<br>10 web meetings |
| WG 6: Documentation and/or marking regarding information relating to material efficiency of the products | 82 | 22 | Unknown |

**Table 4**
Overview of experts and external liaisons involved in JTC10 (CEN and CENELEC, 2020).

| Actors contributing to the standardisation activities | External liaisons |
|---|---|
| Industry representatives | The European Consumer voice in standardisation (ANEC) |
| Laboratories and test houses | Home Appliance Europe (APPLiA) |
| NGOs (especially ECOS and ANEC) | European Committee of Manufactures of Electrical Machines and Power Electronics (CEMEP) |
| European Commission (including JCR) | DigitalEurope |
| ETSI representatives | Environmental Coalition on Standards (ECOS) |
| | European Energy Research Alliance (EERA) |
| | European Heating Industry (EHI) |
| | European Partnership for Energy and the Environment (EPEE) |
| | European Trade Union Confederation (ETUC) |
| | European Steel Association (EUROFER AISBL) |
| | European Metal Trade and Recycling Federation (EUROMETREC) |
| | European Aluminium |
| | Eurovent |
| | European Ventilation Industry Association (EVIA) |
| | Glass for Europe |
| | LightingEurope |
| | International Telecommunication Union (ITU-T SG5) |

**Table 5**
Working groups (WGs), standards and technical reports developed by CEN and CENELEC.

| Working group | Standards | Lead | Published |
|---|---|---|---|
| WG 1 | TR 45550 Definitions related to material efficiency | CENELEC | 2020-12-04 |
| WG 2 | EN 45552 General method for the assessment of the durability of energy-related products | CEN | 2020-03-11 |
| WG 3 | EN 45554 General methods for the assessment of the ability to repair, reuse and upgrade energy-related products | CENELEC | 2020-02-21 |
| WG 4 | EN 45553 General method for the assessment of the ability to remanufacture energy-related products | CENELEC | 2020-07-10 |
| | EN 45556 General method for assessing the proportion of re-used components in energy-related products | CENELEC | 2019-06-07 |
| WG 5 | EN 45555 General methods for assessing the recyclability and recoverability of energy-related products | CEN | 2019-11-27 |
| | EN 45557 General method for assessing the proportion of recycled material content in energy-related products | CEN | 2020-04-29 |
| WG 6 | EN 45558 General method to declare the use of critical raw materials in energy-related products | CENELEC | 2019-03-01 |
| | EN 45559 Methods for providing information relating to material efficiency aspects of energy-related products | CENELEC | 2019-03-01 |

## 5. The role of the EN 4555X series of standards in supporting material efficiency aspects

While at the time of writing there is no official procedure dictating how the EN 4555X series of standards should be used in the ecodesign process, there are some initial indications of the standards' role.

### 5.1. Initial indications of the role of the EN 4555X series of standards

#### 5.1.1. Accelerating the development of standards on material efficiency

Setting requirements for the material efficiency aspects of energy-related products is a fairly new and untouched field. This is the case for both regulators and standardisation organisations, who have both faced challenges due to the need to develop new competences compared to when the Ecodesign Directive mainly focused on energy efficiency (Interviewee #7, 2019). For standardisation organisations, it was not possible to build upon existing standards, and everything had to be developed from scratch, which was a difficult and time-consuming task (Interviewee #1, 2019; Interviewee #2, 2019; Interviewee #4, 2019; Interviewee #5, 2019; Interviewee #6, 2019; Interviewee #7, 2019).

> *The European Commission did not know which requirements they needed to pose. So, what they decided was that first they would like to have generic standards, those are the JTC10 standards, that could give a more generic view of how to assess several aspects of material efficiency; and later based on those, they would have a better understanding of what to request in the implementing measures, and then from the implementing measures, they can again make the request for product specific standards. Then the request becomes very specific.* (Interviewee #9, 2020)

The lack of standards for various aspects of material efficiency has been noted by other scholars (Bundgaard et al., 2017; Tecchio et al., 2017). Standardisation mandate M/543 can be seen as a way for the European Commission to address this gap and accelerate the work on developing standards within the field of material efficiency.

#### 5.1.2. Creating a common language

Standardisation mandate M/543 can also be seen as a way for the European Commission to initiate a consensus process and create a shared understanding between the relevant stakeholders involved in the ecodesign process on the definitions and concepts relevant to material efficiency. Several of the interviewees mentioned that an important role of the mandate was to create a common language between the Commission and other stakeholders (Interviewee #1, 2019; Interviewee #2, 2019; Interviewee #4, 2019; Interviewee #6, 2019; Interviewee #8, 2020). As explained by one of the interviewees (Interviewee #6, 2019):

> *The practical side of things was that there was a need to start discussing material efficiency aspects in the ecodesign regulatory process – I mean the consultation forum and this kind of thing. It was felt that we needed some horizontal, some generic, some general metrics, to be able to structure the discussion, to systematise the – let's say to speak about the same thing for different products. We needed a set of horizontal methods of what material efficiency means, how can we assess it.*

This process was already underway when the new mandate M/543 was formulated after mandate M/529 was rejected. Despite the long process of reformulating the new mandate M/543, several of the interviewees emphasised that the standardisation mandate was still unclear, and that the Commission was unsure of what they asked for (Interviewee #1, 2019; Interviewee #4, 2019; Interviewee #9, 2020). In particular, the lack of background studies and a thorough understanding of the problem was a challenge, and resulted in part from inadequate discussions being held during development of the mandate (Interviewee #4, 2019). This is exemplified by the case of CRM: the Commission initially asked for a method to declare CRM, but according to the recyclers this information is not needed (Interviewee #4, 2019). Another example is the discussion on durability versus reliability and the discussion on remanufacturing and refurbishment (Interviewee #1, 2019):

> *… we actually found that some of the things they* [the Commission, ed.] *requested they effectively asked for the wrong thing … So, they asked for durability but wanted reliability. Which although the two are linked obviously it is quite different and they asked for remanufacturing without understanding that they need to understand what was happening with refurbishment.*

The unclear mandate meant that a lot of time was used at the beginning of the standardisation process to discuss what the task at hand was, and significant time was spent in discussion with the Commission (Interviewee #4, 2019; Interviewee #9, 2020). Furthermore, the unclear mandate also meant that the resulting standards may be different to what was expected by the Commission (Interviewee #9, 2020).

#### 5.1.3. A shopping list for the baseline

The initial idea was that the horizontal standards should work as a baseline for the development of product-specific standards (Interviewee #5, 2019). Thus, when new standardisation mandates under the Ecodesign Directive are issued on material efficiency, a reference is made in the mandate to the relevant horizontal standards (Interviewee #9, 2020). One interviewee also emphasised that the Commission saw the horizontal standards as a kind of "shopping list", from which the standards that are appropriate for that specific product category could be selected (Interviewee #6, 2019). Hence, the intention is not necessarily that each product group should consider every aspect of material efficiency covered by the standards.

### 5.2. Current application of the EN 4555X standards in the ecodesign process

Since the EN 4555X series of standards was published, reference has been made to the standards in preparatory studies and implementing measures. This section investigates how the EN 4555X series standards are used in the preparatory study for mobile phones, smartphones and tablets and the implementing measure for servers and data storage products. The section ends with some reflections on the potential use of the EN4555X series standards in relation to the ESPR.

#### 5.2.1. The use of the EN4555X series of standards in the preparatory study on mobile phones, smartphones and tablets

In February 2021, the preparatory study on mobile phones, smartphones and tablets was published (European Commission et al., 2021). This study provides suggestions for ecodesign requirements on various aspects of material efficiency, including (1) availability of spare parts, (2) access to repair and maintenance information, (3) maximum delivery time of spare parts, (4) maximum price of spare parts, (5) disassembly requirements, (6) requirements for preparation for reuse, (7) reliability, (8) marking of plastic components, and (9) information requirements (including information on CRMs) (European Commission for Internal Market Industry et al., 2021). For several of the specific requirements for the disassembly of batteries and display units, the classifications from Annex A in EN 45554:2020 are used (Table 6)

**Table 6**
Overview of the use of the EN 4555X standards in the preparatory study for mobile phones, smartphones, and tablets (Schischke et al., 2021).

| Material efficiency | Standard | Description |
|---|---|---|
| Disassembly | EN 45554:2020 | The classifications from Annex A in EN 45554:2020 are used for the disassembly requirements for batteries and display units, covering fasteners and connectors (A.4.3), tools (A.4.4), working environment (A.4.5) and skill level (A.4.6). |
| Recycled content | EN 45557:2020 | EN 45557 shall be used if any product-related information voluntarily states the percentage of recycled content for the product or a part thereof. |
| CRMs | EN 45558:2019 | The method specified in EN 45558 should be applied to the declaration of selected CRMs, including gold. |

(European Commission et al., 2021). Furthermore, EN 45557:2020 should be used to state voluntary information on recycled content and EN 45558:2019 should be used to declare CRMs, including gold (Table 6) (European Commission et al., 2021).

In the preparatory study, reference is made directly to both EN 45554:2020 and EN 45557:2020, even though these standards, according to the standardisation organisations, should not be used directly. Furthermore, the reference to EN45554:2020 relates to an informative annex. Finally, not all ecodesign requirements covering material efficiency aspects reference the EN 4555X series of standards, even though the requirements are covered by the standards. For example, the reliability requirements make no reference to the EN 45554:2020 covering durability and reliability.

#### 5.2.2. The use of the EN4555X series of standards in the implementing measure for servers and data storage products

The implementing measure for servers and data storage products was adopted in March 2019 ((3) European Commission, 2019), and amended by a further regulation adopted in February 2021 (European Commission, 2021b). The implementing measure covers several material efficiency requirements, including (1) disassembly for repair and reuse of selected components, (2) availability of a secure data deletion, (3) availability of firmware, and (4) requirements for information supporting material efficiency. The information requirements cover, amongst others, information on CRMs ((3) European Commission, 2019). In the implementing measure, reference is made to the EN 45558:2019 standard on the declaration of CRMs (Table 7), which is also one of the standards that can be applied directly according to the standardisation organisations ((3) European Commission, 2019).

To support the ecodesign requirements for servers and data storage products, a standardisation mandate (M/573) was issued (European Commission, 2021c). The mandate specifies that the standards developed to support the ecodesign requirements on CRMs, availability of firmware and security updates, and disassembly shall be consistent with the principles laid down in the EN 4555X series of standards (Table 7). Furthermore, a specific reference is made to the informative Annex A in the EN 45554:2020 standard. The mandate resulted in a work item plan from ETSI covering several standards encompassing the EN 303 800 series of standards (ETSI, 2022).

**Table 7**
Overview of references to the EN 4555X series of standards in the implementing measure covering servers and data storage products ((3) European Commission, 2019) and standardisation mandate M/573 (European Commission, 2021c).

| Material efficiency | Standard | Description |
|---|---|---|
| *Implementing measure* | | |
| CRMs | EN 45558:2019 | The method specified in EN 45558:2019 should be applied to the declaration of CRMs for cobalt in the batteries and neodymium in hard disk drives. |
| *Standardisation mandate M/573* | | |
| Availability of firmware and security updates | EN 45554:2020 | The method for verifying the availability of firmware and security updates should be consistent with EN 45554:2020. Spare part availability shall be B (independent repair and service providers) and skill level should be C (expert) according to EN 4554:2020. |
| CRMs | EN 45558:2019 | A harmonised standard shall be established for the verification of compliance with the requirement for the provision of information on the weight range (less than 5 g, between 5 g and 25 g, above 25 g). The standard shall ensure consistency with the principles laid down in the EN4555X series of standards, especially EN 45558:2019. |
| Disassembly | EN 45554:2020 | The standards shall ensure consistency with the principles laid down in the EN 4555X series of standards, especially EN 45554:2020 and EN 45559:2019. The required information availability class shall be B (available to independent repair service providers). |

#### 5.2.3. The EN 4555X series of standards role in the ESPR

The proposal for the ESPR was published in 2022, repealing the Ecodesign Directive (European Commission, 2022d). The ESPR continues the work begun under the Ecodesign Directive in setting ecodesign requirements related to energy and material efficiency along with carbon and environmental footprints (European Commission, 2022d). The ecodesign process, to a great extent, stays the same (European Commission, 2022d). Some of the main changes introduced in the ESPR compared to the Ecodesign Directive are a widened product scope and the fact that the ESPR is a regulation wherein product-specific measures are to be set in delegated acts (European Commission, 2022d). However, the ESPR also brings new regulatory opportunities as it provides the framework for establishing a digital product passport, mandatory public procurement criteria, the prevention of the destruction of unsold consumer products, and common requirements for labelling (European Commission, 2022d).

The similarities between the ESPR and the Ecodesign Directive imply that for energy-related products, the 4555X series of standards remains highly relevant within the scope of the ESPR. However, for new product groups within the scope of the ESPR, a direct application of the standards may be difficult, especially for standards that are more product-specific. Furthermore, stakeholders from sectors newly included in the widened regulatory scope were not involved in developing the EN 4555X series of standards. Therefore, a new standardisation mandate may be needed for the new product groups covered by the ESPR. Thus, it is important that the new standards are in line with the principles and definitions in the EN 4555X series of standards to ensure consistency. Future standardisation mandates could also be organised within JTC10 to further support consistency in the work. A new standardisation mandate may also be needed to support new initiatives within the ESPR. However, it is important that the need for new standardisation work does not hinder or delay the development of product-specific standards based on the EN 4555X series of standards.

## 6. Challenges related to the role of the standardisation mandate and the horizontal standards

This study has documented several challenges which can hinder the EN 4555X series of standards in supporting the uptake of material efficiency requirements in the Ecodesign Directive.

### 6.1. Unclear procedures on the role and use of the EN 4555X series of standards

One challenge is the lack of guidelines or procedures specifying how the EN 4555X series of standards should be used. Clear guidelines must be established on what the role of the EN 4555X series of standards should be when developing product-specific standards.

The initial idea was that the EN 4555X series of standards should work as a baseline for new product-specific standards. This was how the EN 4555X series of standards was used in standardisation mandate M/573 for servers and data storage products. Furthermore, references were made directly in the implementation measure to the EN 45558 standard, which is also one of the standards that can be used directly.

In the preparatory study for mobile phones, smart phones, and tablets, on the other hand, reference is made directly to the EN 45554:2020 and EN 45557:2020 standards, despite the fact that these cannot be applied directly. Furthermore, not all ecodesign requirements covering aspects of material efficiency refer to the EN 4555X series of standards, indicating different uses of the EN 4555X series of standards. According

to Schischke et al. (2022), there is also an ongoing discussion amongst the stakeholders involved in the ecodesign process regarding whether or not the EN 4555X series of standards can be used directly in implementing measures through transitional methods or if product-specific standards need to be developed. A challenge of using the EN 455X standards directly is that there will be no consensus process amongst the stakeholders involved in the product-specific standardisation working groups (Schischke et al., 2022). However, if product-specific standards need to be developed, this could lead to a delay in the implementation of material efficiency requirements (Schischke et al., 2022).

### 6.2. Delaying the ecodesign process

This potential for the standardisation process to delay the implementation of ecodesign requirements is a further challenge. If the standards need to be in place before the implementing measures can come into force, this can potentially delay the uptake of material efficiency requirements. As expressed by one of the interviewees (Interviewee #6, 2019):

> *We would not want the standardisation system to hold the regulatory system hostage. So, we don't want to have situations, which already happened unfortunately in many cases, I am sorry to say, where we cannot regulate this because the standardising organisations have not developed the method, or we don't want to develop a method – or they are very late.*

Previously, standardisation has experienced difficulties in keeping up with the ecodesign process (Toulouse, 2014). For this reason, in 2013, standardisation mandate M/495 specified a temporal alignment of the ecodesign process and the standardisation process (Toulouse, 2014). However, of the 27 implementation measures adopted to date, 12 used harmonised standards, 11 used transitional methods, and for four implementing measures it was not possible to identify harmonised standards or transitional methods (Appendix 1). Thus, the widespread and protracted use of transitional methods indicates that the initiatives from M/495 have not been sufficient to ensure that standards are available at the time when the implementing measures enter into force. This also indicates that despite the widespread use of harmonised standards, their use is not a prerequisite for setting specific ecodesign requirements, as transitional methods are also widely applied.

The fact that standardisation processes are consensus processes, wherein agreement among all participants must be reached, means that they are time-consuming and cannot be forced (Interviewee #2, 2019; Interviewee #3, 2019; Interviewee #9, 2020). However, two interviewees also mentioned that the deployment of delaying tactics by some stakeholders also poses a challenge in the standardisation process in general and in relation to the EN 4555X series of standards (Interviewee #5, 2019; Interviewee #6, 2019).

> *… there could be two aims for people from the industry participating. One aim could be they really want to actively influence the topic in a certain direction or the other reason for participation is, say, they want to block the topic. I think we had both in JTC10, we had both groups. […] This is absolutely the reason why companies participate in standardisation, there is only the business interest behind.* (Interviewee #5, 2019)

This is linked to the fact that the development of material efficiency standards is closely connected to the ecodesign policy process and possible future requirements. The continued use of transitional methods could be a way to prevent some stakeholders from using this delaying tactic.

### 6.3. Actor involvement

In the development of the standards, actor involvement has been exceptionally high. This is true both in terms of number, with more than 300 people signing up for the JTC10 (Interviewee #1, 2019) and up to 80–100 participants involved in the meetings (Interviewee #3, 2019; Interviewee #9, 2020), and in terms of broad industry representation, compared to other standardisation processes (Interviewee #5, 2019). Although this exemplifies the huge interest in the development of these standards due to their relevance in connection with future ecodesign requirements, it is also linked to several challenges, including that additional difficulty of reaching consensus among a large number of actors (Interviewee #3, 2019; Interviewee #9, 2020). Another challenge is that many actors were new to the standardisation process, which led to a chaotic beginning in some working groups, where the actors first had to learn the rules for standardisation and the format in which standards are written (Interviewee #3, 2019; Interviewee #9, 2020).

A general challenge to all standardisation processes, which is exacerbated in the case of M/543, is the balance between the different types of actors. As mentioned above, a broad selection of stakeholders was represented in the standardisation work under mandate M/543. However, in the standardisation system it is often private companies that dominate and have the most resources to put into the standardisation work (Interviewee #6, 2019):

> *… in the standardisation system there is a type of stakeholder, namely the industry, who vastly dominate the groups and they have a vast majority of representatives and there is a general lack of balanced representation. I say that from experience myself, having represented environmental NGOs in the standardisation process for some six years now. It is still the case.*

Consequently, standards tend to support the market strategies of the larger corporations with the resources to participate in the technical working groups (Flynn and Hacking, 2019). The risk of an imbalanced representation of stakeholders is that the viewpoints of the actors with the lowest representation will not be considered as strongly as those of the majority of actors. To counteract this, more resources could be allocated to actors representing a broader selection of stakeholders.

## 7. Conclusion

This study provides insight into both the role of the EN 4555X standards and the challenges associated with using standards to support material efficiency aspects in the context of the Ecodesign Directive – an area which few scientific studies have examined. The unique contribution of the study is therefore that it examines a specific standardisation work and its role in supporting circular design of products. Furthermore, the study provides a qunique contributes to understand the role of standardisation in legislation and how it can support circular design and thereby cleaner technologies. Circular design of future products is pivotal for the transition towards environmental sustainability. As the Ecodesign Directive and the ESPR apply to all products imported into the European Union, the standards will also have global contributions. As also international producers will have to comply with the standards. Furthermore, there is an ongoing discussion on pushing the standards into an international level.

Our results show that both the standardisation mandate and the horizontal standards have already played key roles in supporting future material efficiency requirements under the Ecodesign Directive by creating a shared understandings and definitions of the key concepts relevant to material efficiency among stakeholders. Furthermore, standardisation mandate M/543 has also been a way for the European Commission to accelerate the development of standards on various aspects of material efficiency.

The EN 4555X series of standards serves as a shopping list for relevant aspects of material efficiency. Thus, in the new standardisation mandates under the Ecodesign Directive, reference is made to the relevant horizontal standards. Through this approach, the EN4555X series of standards may help to ensure a level playing field and continuity in the development of product-specific standards, ensuring alignment in the understanding of the different material efficiency aspects across the different product groups.

Early indications are that reference to relevant horizontal standards will be made in new standardisation mandates covering material efficiency, as was the case for servers and data storage products. However, in the preparatory study for mobile phones, smartphones and tablets, reference was made directly to the EN 45554:2020 and EN 45557:2020 standards, even though these two standards cannot be applied directly. Furthermore, not all ecodesign requirements covering aspects of material efficiency refer to the EN 4555X series of standards, which indicates different uses of the EN 4555X series of standards in the ecodesign process. In both standardisation mandate M/573 and the preparatory study for mobile phones, smartphones and tablets, references are made to the informative Annex A in EN 45554:2020. The specific references to Annex A indicate that it may play a role in setting future requirements for repair, reuse, and upgrade despite it being purely informative.

Using the M/543 mandate and the appertaining EN 4555X series of standards to support the implementation of material efficiency requirements under the Ecodesign Directive also introduces some challenges. Firstly, the lack of clarity surrounding the role of the EN 4555X series of standards in the ecodesign process make room for different uses of the standards, thereby diminishing their potential to create a level playing field and continuity in the development of product-specific standards. Clear guidelines should be established to counteract this. Secondly, there is also a risk of the standardisation process potentially delaying the ecodesign process and the uptake of material efficiency requirements. Some stakeholders may even employ this as a deliberate tactic to delay the process. Therefore, the use of transitional methods is still relevant to ensure that the standardisation process does not delay the adoption of new material efficiency requirements in the Ecodesign Directive. Finally, during the standardisation process, many stakeholders were involved, including all the most relevant actors. However, the resources these actors must engage during the standardisation process are very different. Consequently, this may lead to imbalanced representation, whereby the actors with the most available resources will have greater influence in the standardisation process. This could be mitigated by providing more resources to stakeholders with a broader representation.

## CRediT authorship contribution statement

**Anja Marie Bundgaard:** has contributed equally to the article, Conceptualization, developing the methods, data collection, Formal analysis, literature review, writing and revising the article. **Rikke Dorothea Huulgaard:** contributed to its further development, developing the methods, data collection, Formal analysis, literature review, writing and revising the article.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

## Appendix 1. Overview of harmonised standards under the Implementing Measures

| | Product groups | Implementing measures | Mandates | Standards reference | Number of standards |
|---|---|---|---|---|---|
| 1 | Circulators | (EU) 622/2012, EC No 641/2009 | M/469 | Harmonised standards | 3 |
| 2 | Computers | EU no 617/2013 | M/545 | Transitional methods | 0 |
| 3 | Household dishwashers | (EU) No 1016/2013 (EU) 2019/2022 | M/481 M/566 | Harmonised standards | 1 |
| 4 | Domestic ovens, hobs and range hoods | (EU) No 66/2014 | | Harmonised standards | 5 |
| 5 | Electric motors | (EC) No 640/2009, (EU) 4/2014 | M/470 | Harmonised standards | 2 |
| 6 | Fans | (EU) No 327/2011 | M/500 | No harmonised standards | 0 |
| 7 | Air conditioners and comfort fans | (EU) 206/2012 | M/488 | Harmonised standards | 8 |
| 8 | Water heaters and hot water storage tanks | (EU) No 814/2013 | M/534 | Transitional methods | 0 |
| 9 | Space heaters | (EU) No 813/2013 | M/535 | Transitional methods | 0 |
| 10 | Local space heaters, solid fuel local space heaters | (EU) 2015/1188, (EU) 2015/1185 | M/550 | Transitional methods | 0 |
| 11 | Solid fuel boilers | (EU) 2015/1189 | M/551 | Transitional methods | 0 |
| 12 | Air heating products, cooling products, high temperature process chillers and fan coil units | (EU) No 2016/2281 | M/560 | Transitional methods | 0 |
| 13 | Electrical lamps and luminaires previously lamps (directional and LED), lamps (non-directional), lamps (fluorescent and professional) | (EU) No 2015/1428 (EU) No 1194/2012, (EU) No 244/2009, (EC) No 859/2009, (EC) No 245/2009, (EU) No 347/2009 | M/495 M/485 | Transitional methods | 0 |
| 14 | Power supplies | (EC) No 278/2009 (EU) No 2019 (1782 | M/450 | Harmonised standards | 1 |
| 15 | Professional refrigerated storage cabinets | (EC) No 2015/1095 | M/495 | Transitional methods | 0 |
| 16 | Household Refrigerating appliances | (EC) No 643/2009 (EU) 2019/2019 | M/459 | Harmonised standards | 1 |
| 17 | Set-top boxes | (EC) No 107/2009 | M/451 | No harmonised standards | 0 |
| 18 | Standby and off mode | (EC) No 1275/2008, (EC) No 801/2013 | M/439 M/544 | Harmonised standards | 4 |
| 19 | Electronic displays and television | (EC) No 642/2009, (EC) No 801/2013 | M/477 | Transitional methods | 0 |
| 20 | Transformers | (EU) No 548/2014 | M/495, Am2 | Harmonised standards | 2 |
| 21 | Household tumble driers | (EU) No 932/2012 | M/495 | Harmonised standards | 2 |

(*continued on next page*)

(*continued*)

| | Product groups | Implementing measures | Mandates | Standards reference | Number of standards |
|---|---|---|---|---|---|
| 22 | Vacuum cleaners | (EU) No 666/2013 | M/540 | Harmonised standards | 4 |
| 23 | Residential ventilation units | (EU) No 1253/2014 | M/537 | Transitional methods | 0 |
| 24 | Household washing machines | (EU) No 1015/2010 (EU) 2019/2023 | M/458 M/566 | Harmonised standards | 2 |
| 25 | Water pumps | (EU) No 547/2012 | M/498 | Transitional methods | |
| 26 | Welding equipment | (EU) 2019/1784 | M/559 | No harmonised standards | 0 |
| 27 | Refrigerating appliances with a direct sales function | (EU) 2019/2024 | | No harmonised standards | 0 |

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