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Drivers and Barriers for "Circular" Consumer Electronics in the European Union

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***Abstract*—The European Union (EU) and the EU member states have adopted a number of policies that can support circular economy developments in the electrical and electronic equipment (EEE) sector, and additional policies have been proposed. The policies include the new Ecodesign Regulation and a new Battery Regulation, and forthcoming rules related to durability and repairability of mobile phones and tablets. This paper, based on an interview study and analysis of the policies, examines what kind of changes the new policies may have on design of EE, and whether practitioners believe the policies will change consumer behavior. Some policies – most notably the Ecodesign Directive, the new Ecodesign Regulation, Energy Labeling, and the Battery Regulation – are expected to have an impact on future design of EEE. Digital Product Passports (DPPs) are considered to have a high potential to support new developments. Mandating that product warranties are shown clearly at the time of purchase also has potential to change manufacturers' product offerings. There were diverging views on how much behavioral changes we can expect from consumers. Interviewed practitioners expect that consumers are likely to react to information about durability/lifetime for expensive products but are not likely to respond to repairability information for cheaper products.**

Keywords—EEE, electronics, ecodesign, digital passport, circular economy, circular electronics

I. Introduction

Electrical and electronic products (EEE) are subject to an increasing number of European Union (EU) laws and policies, which aim to improve their life cycle environmental performance [1], [2], [3]. These include mandatory rules on minimum energy performance during use, mandatory rules on toxic substances in products, and mandatory rules on collection and recycling of used products (extended producer responsibility (EPR)). These "supply side" rules, which ensure that all products on the market adhere to certain standards, have been complemented by voluntary approaches, including voluntary eco-labels and green public procurement. Further, the EU as a mandatory labeling scheme for some product categories, obliging companies to label products according to energy performance.

With the emergence of the Circular Economy as an important policy area in sustainability policy, there is now more focus on how we can save resources by keeping products, components and materials in use longer [1]. This can be done through rules that directly regulate product lifetimes, and through rules that do so in a more indirect manner. Examples of the former are the EU's mandatory Ecodesign requirements on minimum lifetimes for light bulbs and vacuum cleaners [4], while examples of the latter include rules that support repairs, such as mandating producers to provide spare parts [5].

Recently, the EU has adopted a number of laws that will have large implications for the EEE manufacturers and product design. This includes the EU Battery Regulation [6] where Article 11 states that from 2027, products incorporating portable batteries or light means of transport (LMT) batteries shall be designed to ensure batteries are readily removable and replaceable by the end-user. Article 11 also states that "Any natural or legal person that places on the market products incorporating portable batteries or LMT batteries shall ensure that those batteries are available as spare parts of the equipment that they power for a minimum of five years after placing the last unit of the equipment model on the market, with a reasonable and non-discriminatory price for independent professionals and end-users."

Further, the upcoming Ecodesign for Sustainable Products Regulation (ESPR), is expected to form the basis for a regulatory framework that will be used to set increasingly stringent requirements for product durability, lifetime and repairability for various products groups [7]. The recently adopted Ecodesign and mandatory Energy Labeling requirements for smartphones and tablets provides an idea on how these issues can be regulated for electronics. The mandatory Ecodesign requirements [8] state that products must have some resistance for accidental drops or scratches, and protection from dust and water; have sufficiently durable batteries which can withstand at least 800 cycles of charge and discharge while retaining at least 80% of their initial capacity; contain rules on disassembly and repair, including obligations for producers to make critical spare parts available within 5-10 working days, and for 7 years after the end of placement on the market of the last unit of a product model; requires availability of operating system upgrades for longer periods, and; mandates non-discriminatory access for professional repairers to any software or firmware needed for the replacement when conducting repairs. The mandatory Energy label [9] will require producers – from 2025 - to display information on the products' energy efficiency, battery longevity, protection from dust and water and resistance to accidental drops. It will also require them to display how repairable the products is, based on a scoring systems with 6 criteria.

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The EU has also adopted legislative proposals that regulate how information about products' environmental performance can be communicated. The most important one is the proposal for a Green Claims Directive [10]. It sets requirements that all voluntary eco-labeling schemes must comply with, and also sets requirements for the 'green claims' companies make about their products, i.e. statements about their products' environmental performance. Such claims must fulfill certain criteria to guarantee their credibility, and in most cases be verified by an external actor [11].

In addition to the EU rules, several EU Member States have adopted national rules, including a mandatory Repair Index in France, and French ban on planned obsolescence, and the use of repair vouchers in Austria to stimulate repairs [1], [12]. The different EU States also have different rules related to product labeling and information, and this creates a lot of uncertainty among industry, who have protested some national rules, arguing that it is very costly to develop different information and labeling for their products in different European countries [7].

The key laws and legal proposals for supply chains and products, at the EU level and among EU Member States, are outlined in Figure 1. Given all these new policies and laws, which relate both to product design and consumer information, a key question is how they will impact product design, and consumer behavior? The new rules will probably have an impact on product design. A recent review by the Swedish retail association Swedish Commerce [13] noted that a majority of companies surveyed now make efforts to increase product quality and durability, and promote re-use, whereas 30 percent of the surveyed companies worked with developing more options for consumer repairs (up from 20 % of companies the year before). The report however noted that product quality, price and health issues were still more prioritized than sustainability performance by consumers. Further, the surveyed consumers have high expectations that it should be easier to repair products, but almost half the consumers would also prefer getting a new product to repairing the old one when the product is broken. This "duality" has been noted in other studies: consumers want more durable and repairable products, but it's questionable if they really want to pay more for higher quality [14], [26], [28]. A review of the literature shows that this is context-dependent, and that most likely consumers are mainly interested in durability for some product groups, including white goods [14]. It is quite uncertain if they are interested in durability and repairability for all kinds of EEE.

Another trend seems to be that retail chains and some online platforms stress the importance of sustainable EEE. One example is Amazon's listing of Climate Pledge Friendly EEE. Another is the chain Elkjøp Nordic AS that has started to offer more spare parts, offer some repair at the retailer, and increasingly stress the importance of product choice [15].

Another implication is that while the emerging regulatory landscape may lead to more durable and repairable products, this may be compromised by the many conflicting policies related to EEE [2], [16]. These include waste laws that makes recycling costly, waste laws that promote recycling instead of re-use and repair, and tax laws that counteract circular solutions like repair and remanufacturing.

In our discussions with EEE manufacturers, additional barriers have emerged to circular practices. These include the high costs of storing and supplying spare parts, and the high costs of certifying spare parts in some countries. There is also the issue of actors selling dangerous, illegal spare parts online, and the fact that many manufacturers make false claims about their products' green attributes (greenwashing) without any consequences. Another concern is the contradictions between policies and standardization activities promoting circular solutions and rules and standards related to product safety and cybersecurity; currently, these frameworks often clash.

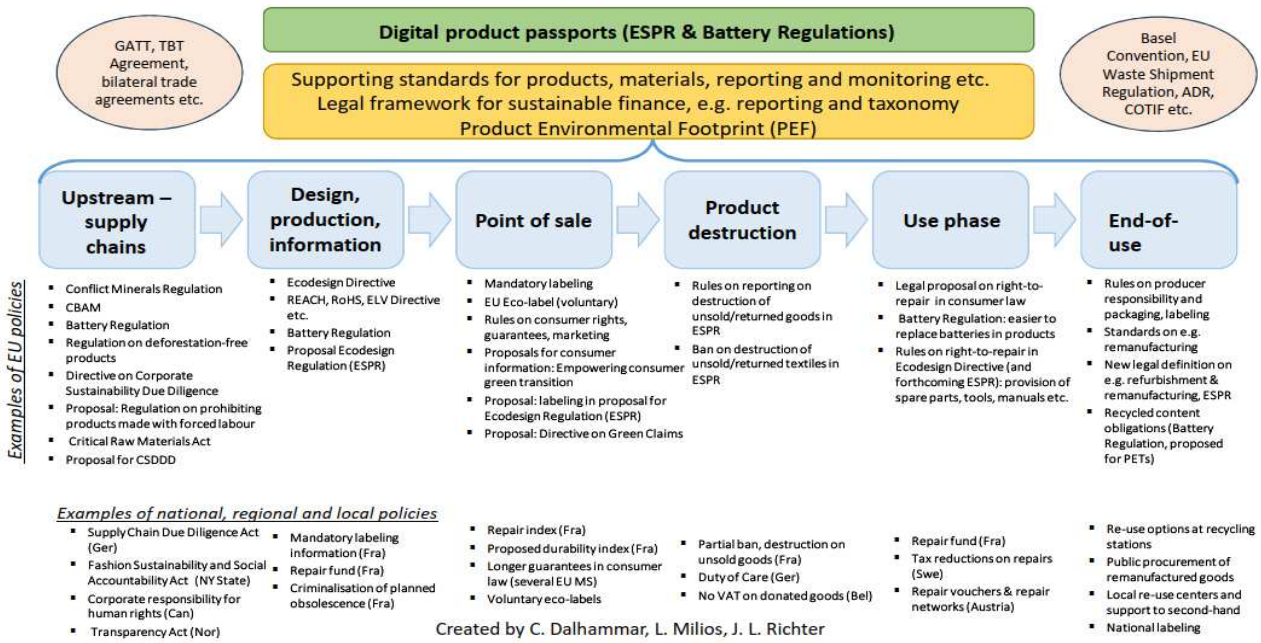

Fig. 1. Overview of Key Laws for Supply Chains and Products

II. AIM, METHODS AND OUTLINE

It is now at a stage where industry actors have started to realize the challenge associated with new rules, and where many EEE manufacturers and retailers have adopted circularity as a guiding principle (see e.g. [17], [18], [19]). We also see how consumers are increasingly becoming more interested in issues like product durability, planned obsolescence and right-to-repair. New tools like 'Digital product passport' envisioned in the ESPR (discussed below) also provides an opportunity for new ways to spread information along product chains.

The aim of this research is therefore to investigate the expected outcomes of the emerging "policy mix". The following questions have guided the research: 1) How is the emerging policy mix expected to influence product design in the future?; 2) Will consumers react to the upcoming policies, and mandatory labeling of product durability and repairability, and if so: how?; 3) Will retailers and other EEE sellers/traders be more careful in product selection in the future, e.g. by prioritizing products that are durable and repairable, and de-select products that are of poor quality?; 4) What are the most important conflicts/contradictions between various rules and standards related to EEE?

The main methods employed in this study are: 1) A literature review; 2) A review and analysis of relevant EEE policies; 3) semi-structured interviews with relevant actors in the EEE sector.

The literature review was performed using relevant search terms (including 'EEE', 'electronics', 'circular', 'ecodesign', 'lifetime', 'repair*', durab*') in different combinations, in Web of Science, LUBSearch and Google scholar. The review of policies included a review of existing and proposed policies in the EU and among EU Member States. It was built on existing studies that have reviewed the policy mix (examples included [1], [2] but also included additional searches for policy proposals, and for relevant literature).

Given the "exploratory" nature of the research, with an aim to understand how existing, adopted (but not yet in force), and proposed policies can be expected to influence industry practices and consumer behavior in the near future, semi-structured interviews with experts was considered the most relevant approach to collect data.

Initially, 25 people were identified through various strategies (personal contacts, interviewees' recommendations on other people to interview, people being visible on social media, people having published studies on developments in the EEE sector). 13 people agreed to be interviewed within the timeframe of the study; cf. Table I for a list of interviewees.

All interviews were conducted 2023-2024, with the bulk of interviews conducted in Feb-March 2024. Four people were interviewed in-person, with the interviews recorded via Zoom. The remaining interviews were conducted online and recorded in Zoom. All interviews were anonymous, in order to allow for an unrestrained exchange of views. The interviews typically took 50 minutes, but some interviews with original equipment manufacturers were longer, up to 90 minutes.

The interview guide was adjusted somewhat depending on the interviewee, but they all contained the following questions:

TABLE I. LIST OF INTERVIEWS

Actor	Information
Original equipment manufacturer (OEM)	Compliance manager. Represents OEM that primarily sells in B2C markets.
Original equipment manufacturer (OEM)	Sustainable design lead. Represents OEM that primarily sells in B2C markets.
Original equipment manufacturer (OEM)	Senior sustainability manager. Represents OEM that primarily sells in B2C markets.
Original equipment manufacturer (OEM)	Product Certification Manager. Represents OEM that primarily sells in B2C markets.
Original equipment manufacturer (OEM)	Regulatory Certification Engineer. Represents OEM that sells in both B2B and B2C markets.
Eco-labeling scheme	Certification manager.
ICT provider	Business Developer Sustainability. Represents provider of ICT solutions, primarily for B2B customers.
ICT Provider	Sustainability specialist. Represents provider of ICT solutions, primarily for B2B customers.
Producer repsonsibility organisation (PRO)	CEO at large European PRO for EEE, who works with developing circularity in producer responsibility schemes.
Non-governmental organisation (NGO)	Circular Economy specialist at environmental NGO.
Remanufacturer	Large European remanufacturer; focus on mobile phones, tablets, displays, laptops and PCs.
Researcher	Researcher who is involved in projects with the electronics industry; focus on design solutions.
Researcher	Researcher who is involved in projects with the electronics industry; general focus (business models, design, policies).

1) **What is your vision for sustainability in the electronics industry?**;

2) **How important are the following strategies for making the electronics industry more sustainable?** (plus a list of 7 strategies: design for longer lifetimes/repairability; new business models; supporting product maintenance and repairs and upgrades; supply chain issues; improved recycling; changes in standardization,; others strategies);

3) **How important do you think these policies will be in changing industry practice, for your products/offerings?** (plus a list of five interventions: the new EU Battery Regulation; EU rules on lifetime/repairability in Ecodesign Directive/mandatory energy label, ESPR; longer legal guarantees for products among EU Member States (national law); Mandatory communication/labeling of manufacturer warranties on products at the retail; the proposals for a EU Directive to strengthen consumer's right to repair);

4) **How do you expect that adopted and proposed policies will influence your customers in the future?** (plus a list of five behavioral changes: Consumers will increasingly consider the durability and repairability of a product at the time of purchase; consumers will increasingly consider the "total cost of ownership" when they buy products in the future; consumers will buy more durable products and take better care of them; consumers will expect manufacturers/retailers to do more repairs; consumers will repair more stuff [for B2B: customers will do more repairs at their own premises];

5) **Do you think that retailers and other service providers will be more careful in the future when they select which products they sell/offer (in services)?** (e.g. due to liabilities, customer expectations on lifetime, support, software updates etc.);

6) **Where do you see conflicts between design objectives?** (e.g. repairable vs. water resistant);

7) **Increasingly, software issues influence the lifetime of products and components: do you consider this to be a large challenge for product design?;**

8) **How important will labeling and certification schemes be in future B2B and B2C markets, do you think?**

The next section provides a short overview of the emerging policy mix for EEE. Section IV provides a short overview of research related to consumer behavior, with a focus on new consumer roles and current knowledge on how interested consumers are in whether products are long-lived (i.e. durable) and repairable. Section V accounts for the results of the interview study. The papers ends with a Concluding Discussion.

In this short paper we do not problematize concepts like 'lifetime', 'durability', 'repairability', 'obsolescence' and so on, nor do we discuss the criteria and standards that can be used to assess e.g. the repairability of a product. For these matters we refer to other reports (e.g. [20].

The EEE in focus of this study is mainly smaller EEE appliances like mobile phones, laptops, ear phones, and speakers, not white goods.

III. Review of policies

A. EU level policies

The EU has a wide range of existing product policies, cf. Table II. Most of these policies apply to many categories of EEE. Further, as stated above, EEE with portable batteries will face new requirements on battery removability under the new EU Battery Regulation, which also has requirements on keeping batteries as spare parts. As was also outlined above, there are new requirements for smartphones and tablets related to durability (e.g. drop tests) and repairability, and these rules is probably a good indication of the type of future legal requirements that will be adopted for other types of EEE products.

The ESPR will replace the Ecodesign Directive, and this will lead to new types of Ecodesign requirements in the future. We can expect more requirements related to lifetime/durability/repairability/disassembly/recyclability, for an increasing number of products groups. Additionally, the ESPR will introduce digital product passports (DPPs). DPPs are defined in the ESPR as: '*a set of data specific to a product that includes the information specified …* [depends on product group] *…that is accessible via electronic means through a data carrier*'.

DPPs are a product-specific data set, which is digitally accessed for registering, processing, and sharing product-related information among a diverse set of actors (including businesses, authorities, and consumers) [21]. DPPs may be used to provide a diverse set of information about a product, including its origin, material composition, disassembly and repair possibilities, and end-of-life options. It also has the potential to be used for market surveillance and to provide consumers with information or digital receipts. DPPs can be coordinated with other polices, e.g. to communicate product environmental performance in relation to eco-labeling criteria.

The European Commission has also proposed a Green Claims Directive [10], see above.

TABLE II. Summary of EU Policies

Intervention Type and Environmental Aspect Addressed	Examples of Environmental Legislation
Eliminating Harmful Substances from Products: These regulations are designed to protect human health, safeguard the environment, and facilitate recycling. Hazardous substances can increase the cost of recycling, render it unfeasible, or even lead to a scenario where there is no demand for the recycled material due to restrictions on its use in new products.	*Chemical and Product Safety Regulations:* • REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) • RoHS (Restriction of Hazardous Substances) Directive • Toy Safety Directive • Product Safety Directive • Battery Directive
Implementing Mandatory Energy Efficiency Standards: These standards ensure that all products meet specified minimum criteria for energy performance.	*Ecodesign Requirements:* Ecodesign Directive, enforced through delegated regulations, setting standards for energy efficiency and environmental design across various products.
Mandating Extended Producer Responsibility: Producers must reach certain collection and recycling targets, and pay for collection and recycling systems; e.g. for packaging, vehicles, batteries, electronics and fishing gear	*Waste Management and Reduction Directives:* • Directive on Packaging and Packaging Waste • ELV (End-of-Life Vehicles) Directive • WEEE (Waste Electrical and Electronic Equipment) Directive • Battery Directive • Directive on the reduction of the impact of certain plastic products on the environment
Establishing Minimum Durability Standards: Certain products, such as vacuum cleaners and lighting, must meet defined standards for durability and lifespan.	*Ecodesign Requirements:* Ecodesign Directive, enforced through delegated regulations, setting standards for energy efficiency and environmental design across various products.
Requiring Availability of Spare Parts and Repair Manuals: Producers are obliged to supply spare parts and repair guides to both professional repair services and consumers, enhancing product longevity and maintainability.	*Ecodesign Requirements:* Ecodesign Directive, enforced through delegated regulations, setting standards for energy efficiency and environmental design across various products.
Compulsory Energy Efficiency Labeling: Producers must label each appliance with an energy label that clearly displays the product's energy efficiency rating.	*Energy efficiency Labeling:* Energy Labeling Regulation, applied through delegated regulations, mandates clear labeling on products to inform consumers about energy consumption.

B. *Policies among EU Member States*

Also EU Member States have adopted several policies (see e.g. [1]), as shown in Table III.

TABLE III. SUMMARY OF MEMBER STATE POLICIES

Intervention	Example of Environmental Legislation in Member State
Consumer Information on Product Reparability	France has implemented a mandatory repair index for a range of products including smartphones, laptops, televisions, washing machines, lawnmowers, vacuum cleaners, dishwashers, and pressure washers. This index, which ranges from 1 to 10, is displayed alongside the product's price tag in physical stores and online platforms. Several other EU countries are in the process of introducing similar measures. •
Consumer Information on Product Durability	France intends to evolve its repair index into a durability index in 2024. This new index will assess factors such as product reliability or robustness (reflecting intrinsic performance, proper maintenance, and relevant consumer information) and upgradability (ensuring products remain functional over time despite technological advancements, including compatibility with software and hardware updates).
Criminalization of Planned Obsolescence	France has made planned obsolescence a criminal offense and has provided a legal definition of the concept • .
Repair Fund	France has established a repair fund requiring producers to contribute to the repair costs of products outside the legal warranty.
Product Labeling and Information	A recent French law requires producers of certain product groups—including electrical and electronic items, packaging, and textiles—to label their products with various criteria such as reparability, sustainability, use of recycled materials, and presence of micro plastics.
Eco-modulation	France has adopted a system of variable fees in Extended Producer Responsibility (EPR) schemes based on the product's lifespan, reparability, and recyclability attributes.

Source: [22]

C. *Implications of the adopted and proposed policies*

The laws will have important implications for EEE manufacturers/importers/producers, who will have to comply with mandatory EU laws, and in some cases also with national laws. For instance, any product sold in France needs to comply with the mandatory French Repair Index. Many corporations are protesting against the national laws, claiming that adjusting products, and product information, for many different national markets is costly. Therefore, they want the EU to harmonize the laws [7]. The ESPR is one of several EU laws that can harmonize national laws, and possible pre-empt the introduction of new national laws, but this is highly uncertain and this process will take time.

One possibility is that manufacturers will change practices. If they anyway are obliged to supply spare parts, they could be interested in develop new offerings around repairs.

It is possible that the laws may also have implications for retailers. If consumers expect longer lifetimes, that spare parts are available, etc., they may primarily contact the retailers when they have complains or want access to spare parts. Then, retailers may have incentives to avoid selling low-performing products. We already know that many retailers de-select some products of poor quality, but the questions is if new rules will strengthen such behavior. Further, we already see how some EEE retailers provide more spare parts, and there are even examples of retailer chains who do some repair in their shops. It's possible this trend will also be strengthened. Retailers will also sell EEE products that must be labelled not just in accordance to energy performance, but in the future also on lifetime and repairability performance. This could provide incentives for mainly selling products of higher quality. All this is of course highly uncertain, and strongly influenced by consumer expectations.

Consumers may become more interested in knowing about durability/lifetime and repairability of products, and over time, as they receive more information about these issues, may increasingly take them into account in their purchasing decisions, and be willing to pay extra for certain product characteristics. Also here, there is uncertainty on how this will play out. Further, consumer behavior is highly dependent upon product group, and other factors, as discussed in the next section.

IV. CONSUMER BEHAVIOR AND CIRCULARITY IN THE EEE SECTOR

A. *New consumer 'roles'?*

Any changes to the "circular" supply of EEE – e.g. an increasing supply of EEE products with more circular characteristics being offered on the market – must be accompanied by consumer behavior changes to be effective. For instance, it does not matter if a product is repairable if consumers choose not to repair it, and designing a very durable product would be a case of "over-engineering" if consumers choose to get rid of it before it has reached the end of its functional lifetime.

There are many new roles citizens can take on to promote more sustainable EEE [cf. [23], going beyond the role of the traditional consumer, for instance: 1) As a *buyer*, a consumer can choose higher-quality, durable and repairable products, and make use of eco-labels and other information to make a more sustainable choice; the consumer can also choose to buy second-hand products and be a *re-user*; 2) It is also possible to be a *maintainer* and take good care of products, or even become a *repairer* (either by taking the product to a repair show or by conducting the repairs oneself; 3) A consumer can also be a *sharer* (sharing some products rather than buying them) or a *renter* (e.g. rent an EEE product for special occasions). In addition to these roles, consumers can also be sellers of used foods, and recyclers, etc.

Some producers and retailers report an increasing willingness among consumers to buy more re-used EEE, e.g. a survey by Recommerce reported more than half of Europeans are willing to buy a used or refurbished phone while 43% of those surveyed also own one [24]. However, studies have found consumers expect to pay less for these

products and there are still complex barriers to consider with consumer preferences for reused and refurbished products [25], [26], [27]. One factor is also the products themselves, with consumers more likely to accept reused and refurbished laptops and phone than reused earbuds [28]. Furthermore, there are still many rather cheap, low-quality EEE available on the market (especially in some product categories), which may reinforces a constantly "updating" mind-set among consumers, where they may view potentially durable products as "semi-disposable" [29].

V. Results from interview study

Here, we account for the most interesting results from the interviews.

The first question related to the interviewees' **vision for sustainability in the EEE sector**. Regarding key strategies for making the EEE sector more sustainable, most interviewees considered the 7 listed strategies (see above) as quite important or very important. All interviewees stressed that strategies that supports longer lifetimes and repair and maintenance of EEE are crucial.

All interviewees stressed the need to increase product lifetimes to support the CE. Some interviewees also stressed the importance of stopping the use of virgin resources for EEE and moving towards closed loops. Some OEMs stressed that a goal is a transition of the EEE industry, but also a larger industrial, societal transition. They emphasize that the EEE sector is dependent upon other sectors, including raw material providers and recyclers, but also choices made by component manufacturers, especially concerning batteries. Some interviewees also stressed social issues, including supply chain issues and the health and safety of people working with EEE recycling. OEMs interviewed stressed that many OEMs (except the largest players) have limited impact over certain components, like batteries. Thus, the potential for sustainable solutions is dependent upon component providers.

Several interviewees stressed the need for avoiding putting too many new products on the market, by keeping existing products and components (of higher quality) in use longer; an approach referred to as "digital sufficiency" by one interviewee. Some interviewees also saw a need to address advertising that aims to "flood" the market with more and more gadgets. Some non-OEM actors stressed that the design solutions by OEMs are crucial for their potential to enable longer lifetimes. This was the case for both the ICT service providers and the remanufacturer. For instance, there are very large differences between brands concerning how long it takes to refurbish/remanufacture a product, due to different design solutions. One researcher stressed that we need to stop the constant focus on adding new features and functions to products to stimulate repeated consumption of new stuff.

One of the researchers interviewed stressed the importance of having a life cycle perspective on EEE, that the "optimal" approach may be different for different types of EEE, and that we need to constantly evolve in our thinking, as "old" approaches may not work in the future.

Regarding **how adopted/expected/proposed EU and Member State rules would affect the design of products in the future**, the interviewees were asked to comment on five interventions (see also above). The first one concerned the EU *Battery Regulation*, with requirements on battery removability and provision of batteries as spare parts. Virtually all interviewees thought that this intervention will have important design implications, as manufacturers must design products with removable batteries. The OEMs thought that such design changes were doable, but may involve trade-offs, especially for products like 'in ear' headphones, where the risk of contamination and negative health aspects were considered an issue. There could even be a problem if 'design for battery removability' have negative aspects on 'design for durability'. Some OEMs were also concerned that the requirements to supply batteries as spare parts for several years could lead to the use of "outdated" technology, and worried about the costs associated with storage of batteries, due to the need for continuous maintenance of them. One of the researchers also stressed that many OEMs now have very long-lasting batteries, and questioned if there should be a lot of focus on replaceable batteries for products where they already have a long life.

All interviewees agreed that consumers should have more rights in relation to product repairability, and some of them stated that some of the new rules should have been adopted earlier. As stated above however, OEMs thought that rules could have been set differently, and maybe made some exemptions. As an example, in a product group where less than 1 % of batteries fail within 7 years, does it make sense to store spare parts for 5 years, when the few products that fail could have been replaced? Thus, an option would be to set rules that would stipulate that over 98 % of batteries would last for a certain number of charging cycles or similar. It was however noted that policymakers, when setting battery rules, did not consider the large uncertainties regarding how long battery would last, especially as this depends on the temperature and charging cycles etc.

The second intervention related to *EU rules on lifetime/repairability in Ecodesign Directive/mandatory energy label/ESPR*. All interviewees thought that these rules would have an impact on product design, as more "general drivers" for longer lifetimes, more repairable products, and better access to spare parts. As an example, when OEMs must supply spare parts, there is reason to maybe standardize more parts, and consider design changes to increase repairability. Some interviewees also pointed out that some information are very likely to be used by consumers, e.g., if they can see how well mobile phones perform in a drop test.

Generally, the NGO interviewee was more pessimistic on how the new rules will affect the products on the market than the other interviewees, stating that that rules were introduced gradually, often mainly covered basic issues like provision of specific spare parts, and often only covered one product group at the time.

Several interviews brought up the potential of Digital product passports (DPPs). Some argued that DPPs are a bit "overhyped", but if we can get them in place, they will have high potential to be useful over time, e.g. as regards traceability of products, and the potential to use them for supplying information required in eco-labeling etc. One researcher stated that DPPs can be the key enabler for transparency for the entire EEE supply chains. Some interviewees had quite high expectations for DPPs, but only if they are designed and applied in the right way. The interviewed Producer Responsibility Organization (PRO) stated that DPPs could be used for developing producer responsibility schemes, e.g. price differentiation between products (i.e. modular fees), when there is the right type of

information available. This could include information about toxic substances. It could also make it possible to ensure that individual producers get their own products back and ensure that homogenous streams of plastics can be sold to actors who wants them, avoiding mixing of plastic qualities etc.; today, this is too expensive. Thus, DPP and digitalization can enable logistical solutions that are too expensive today and allow for more differentiation between products. Some OEMs also thought the DPP could be used in interesting ways, not least to communicate with consumers and provide information about spare part availability etc.

As regards software issues, several interviewees pointed out that hardware-software interactions have been a major cause of premature obsolescence and stated that they think EU rules – requiring the supply of software for a minimum number of years, and also mandating labeling of how long products will be supported by software updates – will to a large extent address this problem. However, the issues will continue to be important, and we see some developments going in the wrong directive. One interviewee pointed to the decision to close down 2G and 3G networks in some countries, making products connected to these network becoming obsolete.

As regards the third intervention – EU member states *implementing longer mandatory legal guarantees for products* – the interviewees did not consider this to be a main driver for design changes. One stated reason was that consumer are not aware of their rights; for instance, some EU member states have a three-year guarantee, but many consumers believe it's a 1-year guarantee and in any case, most often they do not save receipts. In the B2B sectors, commercial warranties are the key tools for regulating guarantees. Further, for OEMs of high-quality products, a three-year legal guarantee is not really an issue.

The fourth *potential intervention is mandatory communication - through mandatory labeling of manufacturer warranties on products at the retail level*. Several interviewees thought that this could be a potentially powerful policy, provided that consumers obtain clear, easy-to-understand information. It has the potential to influence not only consumers, but it may also influence retailers' choice of products to market and sell, as several interviewees thought that retailer may become "pickier" in the future regarding what products they sell.

The fifth intervention was the *European Commission's proposal to strengthen consumer right to repair* through consumer law. The interviewees generally knew little about the policy and did not think it would be a powerful driver for changes in product design.

One interviewee, commenting on all the proposed and adopted policies by the EU and EU member states, commented: "*It's incredible how much stuff we do that will have no effect at all*".

Several interviewees pointed out that the rules may lead to undesired design changes, and sub-optimization. For instance, they saw a potential that products were made more brittle, and repairable rather than durable. Further, several interviewees pointed out that we may need to challenge current design and market trends – e.g. slimmer and thinner products – in order to have a more circular design.

One researcher pointed out that we have already seen in the last couple of years that many EEE, especially smartphones, are becoming more modular, and that it is likely that many OEMs will increase modularity for an increasing number of EEE. The interviewee also pointed out that there is an opportunity to standardize some components, especially batteries.

Several interviewees, especially OEMs, pointed to ***internal inconsistencies*** among policies and product standards (i.e. standardization). The issues brought up included: many safety standards promote the use of more flame retardants, which is barrier for plastics recycling; rules on cybersecurity and data security may stop circular activities (e.g. re-use of batteries; or data protection rules that make it harder to monitor product use to e.g. optimize battery lifetime). Several interviewees stressed that it was hard to convince people involved in standardization to pay more attention to sustainability issues.

Regarding ***laws and policies adopted by EU member states***, such as the French Repair Index, several OEM interviewees had a positive view of the intentions behind the policies, and expressed support for national rules, yet were worried about the costs of compliance. OEMs already face extra costs because of different labeling requirements – e.g. for recycling purposes – in different EU countries, and now expressed concerns that there would be additional national rules related to product labeling and information about products. Thus, they hoped that not all EU member states would have their own rules, but rather that many practices would be harmonized by the EU.

Some interviewees brought up ***problematic practices outside the EU***, which makes it hard for them to offer circular solutions outside the EU. One example was that some countries charged a high price for certifying spare parts. The legal uncertainties regarding liabilities for repaired products in some countries were considered a barrier for offering repair solutions there. Another problem brought up – related to repairability of products and spare parts – was that there are actors that offer dangerous, illegal spare parts online. Consumers may think that these are connected to OEMs. The NGO also brought up the deficiencies in EU rules to address e-commerce actors, noting how the ESPR rules have several loopholes.

The next question related to **potential future changes in consumer behavior**. A first issue discussed was whether *consumers will increasingly consider the durability and repairability of a product at the time of purchase*. Here, many interviewees pointed out that consumers will be more interested in information about durability/lifetimes, but mostly for more expensive products, and have less interest in information about repairability, especially for cheaper products.

There were however clear differences between the interviewees in their opinions of how much behavior change we can expect. Generally, some of the OEMs thought that we would see interesting changes in consumer behavior, and expressed hopes that the policies would lead to higher sales of higher quality products, whereas the NGO representative was more skeptical, stating that many people will continue to choose the cheapest products.

The NGO also stressed the importance of consumer trusting the information provided. For the information to be

used, it is crucial that trust is created. This also requires market surveillance of OEMs' claims. Further, it requires an approach to surveil products sold over e-commerce.

The PRO interviewed pointed out that many consumers still buy very cheap products, despite knowing the quality is often poor, and this habit can be hard to change. One of the researchers pointed out that it is necessary to challenge consumer preferences if we are to become circular. One example brought up was that consumers wanted smaller, slimmer products, but more modular design to increase lifetime and repairability may be difficult if products are very small/thin. One OEM also meant that they design products with functions that very few consumers use, and questioned if they should continue the efforts to include more and more functions, which may have several negative consequences. The PRO pointed out that many of the adopted/proposed policies will have very limited effects on behavior, and that policymakers must be better at showing consumers how they can benefit from circular offerings. One positive trend brought up by some interviewees is that an increasing number of consumers, especially young ones, are very much willing to buy refurbished cell phones.

Further, one interviewee stressed that the fact that many retailers now offer high-quality refurbished products will lead to a situation where the consumers will no longer see a clear distinction between new and used EEE, and rather look more at quality and warranties offered. Having such offerings at retailers – not just online - will allow consumers to really test the products. However, one interviewee stressed that this development will not necessarily be beneficial to OEMs.

The second behavior change proposed was that *consumers will increasingly consider the "total cost of ownership" (TCO) when they buy products in the future*. Here, the opinions were varied; some interviewees were doubtful, one of them stating that most consumers do not even consider the TCP when buying a car. Other interviewees were more positive, stating that we may see some changes in this direction, at least for more costly products.

A third intervention was: *consumers will buy more durable products and take better care of them*. Also here, the opinions varied. A general takeaway is that this mainly applies to some categories of EEE, where people look for durability. Further, some interviewees pointed out at that this comes down to individual consumers' behavior and character. As noted by some interviewees, the technological developments matter: young people buy more refurbished phones because the new models do not offer much more utility than the old ones. One interviewee pointed out that we will probably have more durable EEE in the near future, but it may depend more on the high price of some EEE, and slowed down technological developments, than on policies acting as drivers. The interviewed NGO also pointed to the fact that many consumers buying Fair Phones but treat them as other phones; e.g. replacing them instead of replacing parts to keep them in life longer.

A fourth intervention was that *consumers will expect manufacturers/retailers to do more repairs*. Some interviewees answered this in the positive, pointing to some consumer trends, and the fact that some retailers offer repair services. Other pointed to the increasing popularity of repair cafés. Several interviewees however stressed that changing consumer behavior is a slow process. One interviewee stressed the importance of policies that are visible to consumers and offer economic incentives, such as the Austrian repair vouchers.

A fifth intervention was whether consumers will become more willing to engage with DIY repair. Several interviewees stressed that consumer repairs must be very easy and convenient if they are to do it themselves, and that the low price of new products undermine the willingness to repair. One interviewee stressed that some people do DIY because professional repair services are so expensive, and that many consumers are becoming increasingly more convenient, and thus repair services or DIY repairs must be very easy and attractive (e.g. a 2-minute video on Youtube, with easy instructions). One interviewee pointed out that many EEE products die because of poor maintenance, and that OEMs should offer more support for maintenance, not just repair.

The ICT providers who worked more with B2B were asked if *their customers will repair more stuff at their own premises*. While one interviewee noticed some developments in this direction, with some customers' IT departments doing more upgrades/repairs themselves, there was also tendencies in the opposite direction: all ICT activity is outsourced to the ICT providers as this is more convenient.

An interesting issue is **whether retailers and service providers will be more careful in what products they sell in the future**. Several OEMs saw indications in this direction. They thought that 1) retailers may deselect more poor products form their offerings in the future; 2) retailers will increasingly market more sustainable products in "green ranges" (e.g. like Amazon's Climate Pledge Friendly) and encourage consumers to but these products; 3) retailers and online marketplaces are increasingly hiring outside actors to ensure that a third party has verified OEMs' green claims about their products. Some interviewees agreed that this may be a trend, but, at the same time, that many retailers still sell poor-quality products, as there is a demand, and that retailers who goes "all-in" on more expensive, sustainable products, may go out of business, as consumers still demand cheap products.

Large online retailers can also be influential as they have a large say over whether products sold online must comply with national rules. One OEM referred to the French Repair Index: as one large online retailer required that certain products should be labeled in accordance with the French scheme, the OEM had to comply.

One interviewee stated that we also see some retailers who do not take responsibility for the products they sell, and that retailers even try to avoid all responsibilities for the products they sell by referring all consumer queries to the OEMs.

Another interviewee was less positive towards this development, e.g. because some consumers buy cheap products and do not expect high performance, and that OEMs also make money by selling spare parts and repair services for higher-quality products and these revenue streams will be lower if products and components last longer. One interviewee also stressed that we have to be careful with how we communicate issues like "regulating away" poor products, or stopping certain products, as consumers may perceive this as a way to stop them from buying cheap stuff.

Currently, **eco-labeling for EEE** works for B2B but is not very popular in B2C settings. Regarding the future of eco-labeling, there were several perspectives from the

interviewees. One interviewee meant that it will not work very well in B2C settings as consumers will not – unlike companies – have sustainability objectives that they must strive for, nor be held accountable for what they purchase by various stakeholders. One of the researchers also stated that there is a risk of "information overload" for consumers, now that we will also see mandatory labeling applied for EEE on e.g. repairability and lifetime, and therefore voluntary labels may add to the confusion. Other saw a role for eco-labels in the future, but mostly for B2B settings. The interviewee from labeling saw new roles that labeling schemes can take. Most importantly, online platforms and retailers have started to hire labeling schemes to verify the claims about the products they sell and identify "best in class" products.

Not all EEE sold in B2B markets are currently addressed by eco-labeling criteria, but there could be an opportunity to develop a more "generic" sustainability labeling for all kinds of EEE in the future.

While there are some quality labeling schemes to ensure the quality of re-used EEE (see [30], the manufacturer interviewed stated that for them, labeling is not very interesting; instead, they key to attract consumers is to offer a long warranty.

VI. CONCLUDING DISCUSSION

The interviews in this research give insights into how the adopted and expected policies may change product offerings on the market in the near future. OEMs are most likely to be affected by the Battery Regulation, the Ecodesign criteria set under the Ecodesign Directive/ESPR, and mandatory Energy Labeling. If retailers are mandated to show how long warranties OEMs offer, this can also provide incentives for designing longer-lasting products. While some future design changes are certain, e.g. making products more repairable by enabling battery replacement, and OEMs being obligated to offer spare parts, other changes like longer lifetime, modularity etc., are less certain. It is, however, likely that we will see more modular design, more "design for repairability" and, possibly an increased standardization of components. The interviews indicated that there are still large differences between brands regarding e.g. how easy it is to disassemble and refurbish a laptop, which has large implications for the costs of repairs and refurbishment.

Some interviewees, and most notably OEMs, stressed that the current regulatory framework has several inconsistencies. Thus, they argued for improved coordination not just among legal frameworks, but also in relation to European and international standardization efforts. Further, the interviews pointed to problematic issues that cannot be resolved by the EU alone, but may require the EU to engage with other nations. These include the high costs for certifying spare parts in some countries, and the fact that some e-commerce actors sell dangerous spare parts. It is clear there is a need for identifying trade-offs and tensions in the policy framework and discussing the balance between competing objectives.

Regarding changes to consumer behavior, there were diverging perspectives on how much behavior change we can expect. There was some agreement that consumers are more likely to act upon information about durability/lifetime for more expensive products, and less likely to act upon information about repairability for most categories of EEE. As regards consumer "roles", we already see some changes, with more consumers buying refurbished mobile phones, and an increasing interest for repairs among some consumer groups. However, many interviewees stressed that changes in consumer behavior is a slow process, and that many consumers still want to buy cheap products, not expecting them to be of high quality. This points to the need for larger shifts in cultural and societal norms that indeed will likely be slower [12].

An interesting subject raised by the interviewees concerned whether retailers and online platforms will increasingly deselect poor quality products, offer more repair services, and possibly also try to "reward" more sustainable products. Some interviewees thought that we would see such developments, whereas other interviewees were more skeptical. Future research could examine the role of retailers as "gatekeepers" for sustainable products.

Generally, the interviewees expressed uncertainty on how the emerging policy mix will influence manufacturers and consumers. This is quite natural, as some policies have been proposed but not yet adopted, whereas other policies have been adopted but it is not clear how rules should be interpreted. This implies that EU Member states, who are responsible for market surveillance, conduct proper monitoring, and cooperate with other member states and the European Commission. Enforcement through market surveillance is necessary to avoid situations such as online platforms selling non-compliant products, or brands offering poor-quality products and then quickly disappearing from the market to avoid liabilities.

This research has highlighted key challenges and trade-offs in the current and emerging EU policy framework to drive more circular consumer products. As more these policies mature, it is important to continue to evaluate their performance.

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