Breaking down the barriers to extending the lifetime of smartphones and laptops

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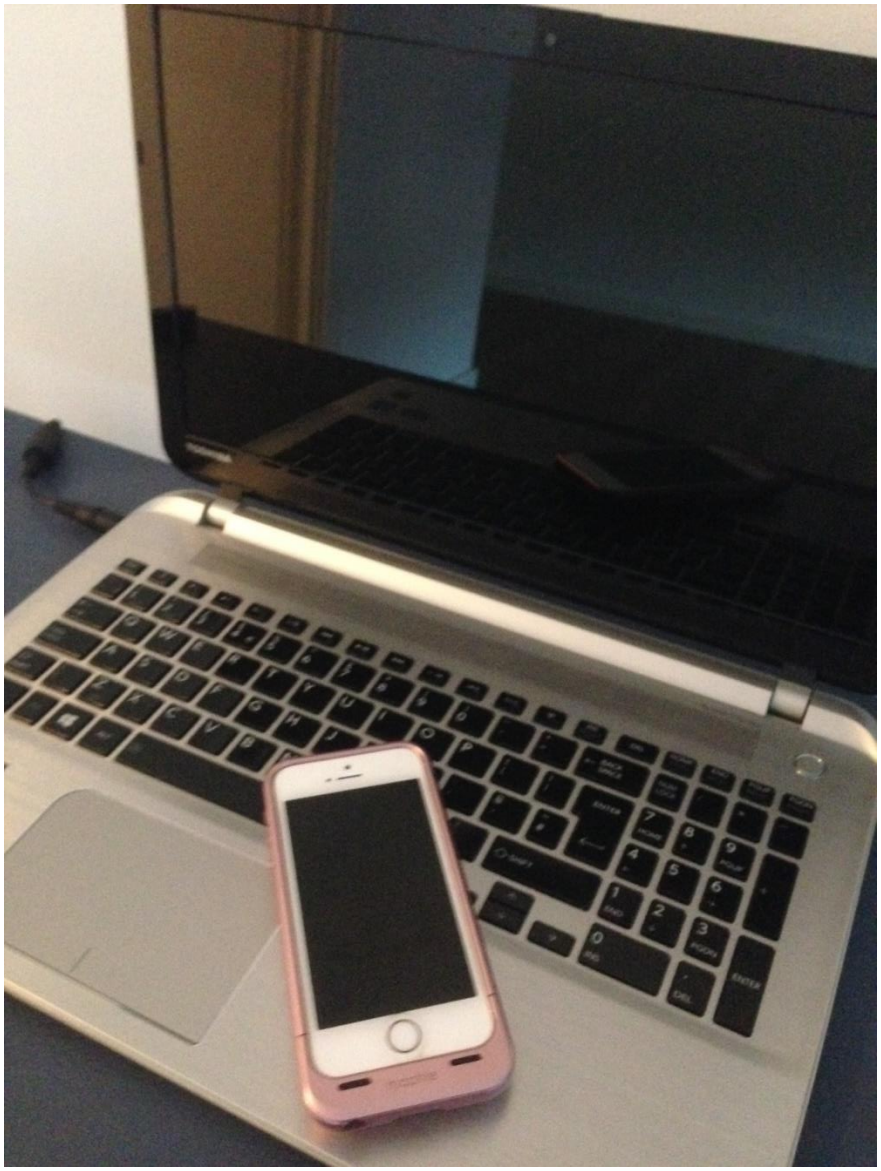

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Abstract

This master thesis investigates the possible measures that might be adopted by the European Union to help extending the lifetime of smartphones and laptops. In the beginning of the project, the importance of extending the lifetime of smartphones and laptops is highlighted. Then, the instruments available at the EU level, that might help to extending the lifetime of smartphones and laptops are discussed. Furthermore, to help answer the main research question which is: *"How can European Union (EU) break down the barriers to extending the lifetime of smartphones and laptops?"* three sub-questions were formulated. The first sub-question aimed to provide information regarding the environmental impacts caused by smartphones and laptops. The purpose of the second sub-question was to identify the main barriers that prevent the lifetime extension of smartphones and laptops, while the third sub-question aimed to identify the main possible measures that might be taken by the EU to help address this issue.

The findings revealed that introducing ecodesign requirements for products to address issues such as: software and firmware updates, repairability of the products, spare parts availability, repair information could be the most important measure to be taken by the EU to help extending the lifetime of smartphones and laptops.

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List of Abbreviations

BOL- Beginning of Life
EEE- Electrical and Electronic Equipment
EOL- End of Life
EU- European Union
GHG-Greenhouse Gas Emissions
GPP-Green Public Procurement
GWP-Global Warming Potential
ICT- Information and Communication Technology
MOL- Middle of Life
Mt- Million tons
PL-Product Lifetime
PLE-Product Lifetime Extension

1.Introduction

The electrical and electronic equipment (EEE) industry has increased over the past decade and is expected to continue to grow. This industry is one of the largest in Europe and the world and is a resource intensive industry (Bachér et al. 2020) For example, producing a mobile phone involves up to 60 various elements from the periodic table. Some of those elements are included on the European Commission's list of critical raw materials (Bachér et al. 2020) Extracting, refining and recovering materials for EEE require large amounts of water, chemicals and energy (Bachér et al. 2020).The statistics from the "Global e-waste monitor 2020", revealed that in 2019, the world generated 53,6 million tons (Mt) of electronic waste, representing an average of 7,3 kg per capita (Forti et al. 2020) The global generation of electronic waste increased by 9,2 Mt since 2014 and is expected to grow to 74,7 Mt by 2030 (Forti et al. 2020) On average, Europeans generated in 2019, 16,2 kg of electronic waste a year, per capita, ranking the first worldwide when it comes to electronic waste generation per capita (Forti et al. 2020)

EEE can be found in almost every European Union (EU) household and consumers buy new appliances regularly(Bachér et al. 2020). Regarding the total consumption of EEE in the EU in 2017, the household expenditure was estimated to 421 billion EUR (Bachér et al. 2020) Of the total consumption of EEE, communication products such as mobile phones represented 50 percent, 26 percent was of products such as laptops, household appliances 16 percent, while tools and equipment for gardens and houses was of 8 percent (Bachér et al. 2020)

In the last decades, the Information and Communication Technology (ICT) devices, (such as laptops, smartphones, tablets, televisions) have transformed the way people communicate, work and travel. As people rely more and more on these devices, the need for energy to produce and electricity to power these devices has grown rapidly (Belkhir and Elmeligi, 2018).

During their entire lifecycle, EEE cause various environmental impacts. The extraction of raw materials is highly material and energy intensive. The mining industry is depending on fossil fuels and as a result, is generating CO_2 emissions (Bachér et al. 2020).The share of the different lifecycle phases of EEE on global warming differs greatly between products (Bachér et al., 2020)

Extending the lifetime of products can reduce waste generation and can lead to environmental benefits because it saves the energy and resources which otherwise would be used to produce new products (Bachér et al., 2020)

2.Circular Economy and lifetime extension

Circular economy

Since this study intends to investigate the prolonging of the lifetime of two consumer electronics products, it is important to introduce the concept of circular economy and lifetime extension.

According to Ellen MacArthur Foundation (2015) the concept of circular economy is characterized as " *an economy that is restorative and regenerative by design*". According to (Laitala et al., 2021), repair should be considered as an important part of the circular economy, due to the contribution to increasing the product lifetime and as a result, better resource utilization and less waste. Repair is a key activity for prolonging the lifetime of the products (Woidasky and Cetinkaya 2021). Besides the repair and recirculation of products (reuse) which are regarded as key elements of circular economy, service and maintenance activities can also contribute to prolonging the lifetime of products (Woidasky and Cetinkaya 2021).

A circular economy approach involves to close the value chain into a loop by performing activities such as: reusing, repairing, refurbishing, recycling, decreasing the mining and the waste (Rizos et al. 2019).For example, in the figure below are depicted the steps for a mobile phone value chain, in a circular economy(Rizos et al. 2019)

Figure 1 Mobile phone value chain (Rizos et al., 2019)

The value chain starts with mining and the raw material extraction to supply input into the manufacturing of components for mobile phones. The next step is represented by the manufacturing of the components and assembly of the mobile phones. The next stage is retail and usage (Rizos et al. 2019) At the end of their lifetime, through collection and proper recycling, mobile phones can enter a circular value chain. The innermost, lighter green circle illustrates the potential for additional lives for the mobile phones, which can be achieved through repair, reuse, refurbishment or resold(Rizos et al. 2019)

Lifetime extension

Definition

Product lifetime (PL) represent the useful life of a product which starts in the moment a product is released for use and ends when the product became obsolete (Ertz et al., 2019). Product lifetime and the concept of obsolescence are connected (Bachér et al., 2020). Obsolescence represent the condition of no longer being used or useful, therefore a product become obsolete at the end of its lifetime (Bachér et al., 2020).

Products can have only one lifetime but one or multiple use cycles (Woidasky and Cetinkaya 2021). PL extension (PLE) represents the use cycles during a PL which prevent the product's obsolescence. PL extension can therefore limit the waste production and can prevent serious environmental threats (Ertz et al., 2019).

Strategies

According to Khan et al.(2018) a product life can be extended through several strategies. Based on their definition Khan et al. (2018) classified the strategies into three product lifecycle stages**:** Beginning of Life (BOL), Middle of Life (MOL), and End of Life (EOL). You can see in the Table 1 below some of the product life extension strategies, classified based on the lifecycle phase:

Lifecycle phase	Product life extension strategy
Beginning of Life	Design for durability Design for ease of maintenance and repair Design for upgradability Design for disassembly and reassembly
Middle of Life	Product reuse/ redistribute Preventative maintenance Repair
End of Life	Remanufacture with upgrade Remanufacture Refurbish Recycle

Table 1: Product life extension strategies-based on (Khan et al., 2018)

3. Consumer electronic products

This section which is divided in two sub sections presents information regarding the lifetime extension of the consumer electronic products with a focus on smartphones and laptops, which are the topic of this research, and information about the instruments available at the EU level, which might help to extend the lifetime of the consumer electronic products. The aim of this section is to provide a framework for the study and to present the context of the research.

3.1 Lifetime in the consumer electronics sector

The first sub section will start by giving an overview of the consumer electronic products lifetime extension and emphasizes the lifetime extension of smartphones and laptops. The purpose is to present the arguments for selecting the smartphones and laptops among other consumer electronics, to be investigated. Furthermore, the next point argues why is important to extend the lifetime of the smartphones and laptops. In the last point of the 3.1. subsection, an overview of the actors that might contribute to extend the lifetime of smartphones and laptops is presented.

3.1.1. Extending the lifetime of the consumer electronic products

Different studies have examined the lifetime extension and the optimal replacement moment of a range of consumer electronic products. Products such as washing machines, refrigerators, TVs, mobile phones, laptops, vacuum cleaners were found to be the most frequent products analysed by the researchers. A study conducted by Bakker and Schuit (2017) revealed that for mobile phones product lifetime extension is a recommendable strategy, environmentally speaking. Moreover, in the case of laptops, lifetime extension can lead to environmental benefits and the optimal replacement moment suggesting being at least 7 years (Bakker and Schuit, 2017). In the vacuum cleaner case, the study showed that the optimal replacement moment is depending on the energy efficiency improvement. If the new model does not provide much energy efficiency gain, the best strategy is to repair the old vacuum cleaner (Bakker and Schuit, 2017). Concerning the washing machines, their average lifetime is considered to be 12 years (Hennies and Stamminger, 2016)

A more recent report has analysed the washing machines, notebook computers, vacuum cleaners and smartphones to see the contribution of the different phases (production, transport, use and end-of life) to global warming (EEB, 2019). The results showed that for the vacuum cleaners the impact of the non-use phases on global warming ranges between 10% and 31% while for the washing machines between 18% and 31% of the Global Warming Potential (GWP) came from their non-use phases(EEB, 2019). Regarding the notebook computers and smartphones it seems that the shares of GWP of the non-uses phases are between 40% and 64% for notebooks and between 51% and 92% for smartphones(EEB, 2019). The authors explored what are the implications of extending the lifetime of the products analysed beyond their typical lifetimes and concluded that under normal conditions it always make sense to prolong the lifetime of the products beyond their typical lifetimes(EEB 2019). To offset for the greenhouse gas emissions from production, distribution and disposal, the washing machines should last for 25 to 40 years instead of 11 years, the vacuum cleaners should last for 18 to 48 years instead of 5-8 years (EEB, 2019). In the notebooks and smartphones cases it is preferably to keep them in use for as long as possible, because the newer products are more energy consuming that the old ones (EEB, 2019)

Lifetime extension should be taken into account even when considering an improvement rate of the energy efficiency of about 5% annually and the products should be kept in circulation beyond their typical lifespan, as you can see in the figure 2 below (EEB, 2019).

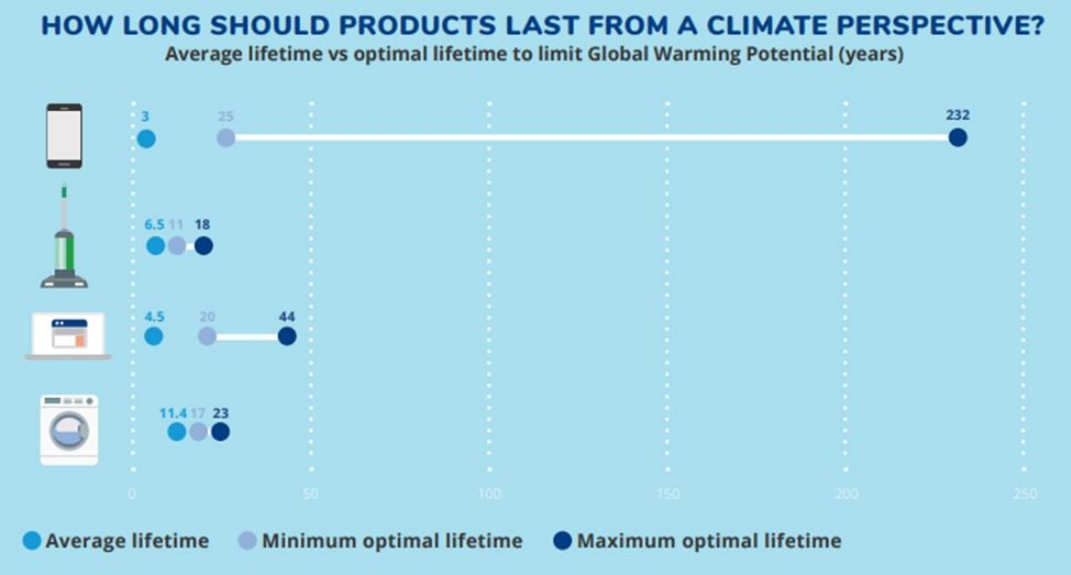

Figure 2 Average vs optimal lifetime for smartphones, vacuum cleaners, notebook computers and washing machines (EEB, 2019)

What could be the environmental benefits regarding the reduction of the GWP through prolonging the lifetime of the products analysed, was another point in the study conducted by EEB(2019). The results revealed that by extending the lifetime of all smartphones, notebooks, vacuum cleaners and washing machines in the EU by 1 year would save annually by 2030, around 4 Mt CO_2 (see figure 3) (EEB, 2019).The biggest contribution of the 4 Mt CO_2 equivalent savings would come from the lifetime extension of smartphones and notebooks with 2,1 Mt CO_2 equivalent and 1,6 Mt CO_2 equivalent respectively, savings per year. Moreover, by extending the lifetime of the products dicussed above by 5 year would help to save around 12 Mt CO_2 equivalent annually by 2030 (EEB 2019)

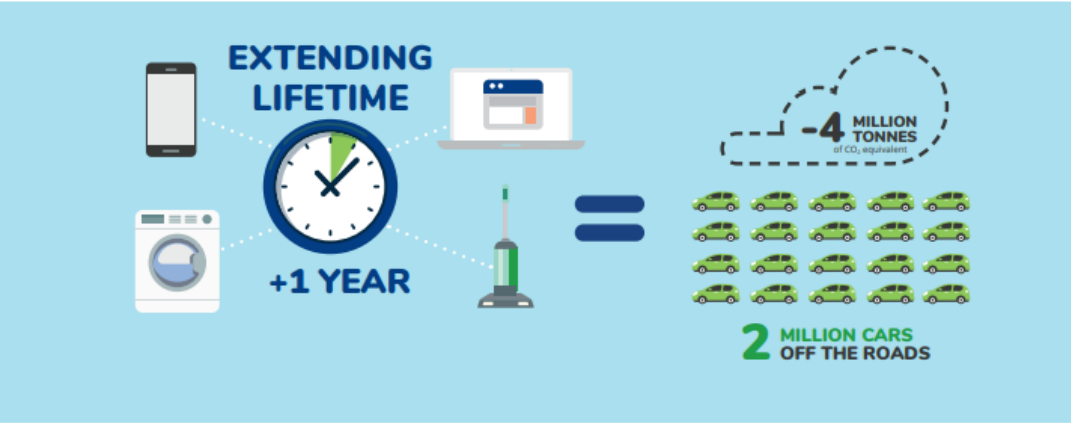

Figure 3 Environmental benefits in terms of reducing GWP by extending the lifetime by 1 year (EEB, 2019)

3.1.2. Smartphones and laptops-the importance of extending their lifetime

Smartphones were created in the late 1990s and over time they become an extremely popular tech device. It is estimated that in 2020 1,7 billion units were sold worldwide (Cordella et al., 2021).The production and use of smartphones leads to environmental impacts such as emissions of greenhouse gases (GHG) and critical raw material depletion (Cordella et al. 2021). For example, the production footprint reported by Apple for their iPhone 6 model and iPhone 7 plus model is ranging from 43,2 kg CO_2-equivalent to 52,2 kg CO_2-equivalent respectively (Belkhir and Elmeligi, 2018). According to Belkhir and Elmeligi (2018), the greenhouse gas emissions of smartphones grew in the last 10 years from 17 Mt CO_2-equivalent to 125 Mt CO_2-equivalent. This is because the production energy represent about 85-95% of the smartphone's lifecycle annual footprint and due to the smartphone's short average useful life of 2 years (Belkhir and Elmeligi, 2018)

It is important for the environment to provide the longest life possible for the smartphones since in the European Union 6,7 smartphones are sold per second (Right to Repair, 2020a). Moreover, it is estimated that the annual climate impact of the smartphones in Europe represent more than 14 million tonnes of CO_2 equivalent which exceeds the annual emission of Latvia (Right to Repair, 2020a). Extending the lifetime by just one year would help to avoid more than 2 million tonnes of emissions (Right to Repair, 2020a). Compared to other household electronic and ICT products, smartphones tend to have a shorter average lifetime. The best way to reduce the smartphone's impact is to keep them in use for as long as possible (Right to Repair, 2020a)

Laptops and notebooks are also very popular tech devices, about 166 million of such devices being sold annually worldwide (Woidasky and Cetinkaya, 2021). The main environmental impacts of these devices derive from their manufacturing phase, this accounting for 56% of the life cycle impact on global warming (Woidasky and Cetinkaya, 2021). Environmentally speaking, for laptops, unlike other electrical or electronical equipment (EEE) it is not appropriate the replacement of older laptops with devices which are more energy efficient. As a result, the use phase length of laptops is of high importance (Woidasky and Cetinkaya, 2021). Sadly, in recent

years the use phase of laptops was observed to become shorter ranging between 3 and 6 years (Woidasky and Cetinkaya, 2021; Hennies and Stamminger, 2016). Even though laptops can receive a second life with only little upgrades, they are often prematurely substitute with new ones (ECOS, 2020). Extending the lifetime of laptops either through repair, second use or remanufacture, delays the material impacts generated by the production of a new laptop (ECOS, 2020)

All the above points suggest the necessity to take actions for extending the lifetime of smartphones and laptops.

3.1.3. Actors who can contribute to the lifetime extension of the smartphones and laptops

The purpose of this section is to give an overview of the important actors that might help extending the lifetime of smartphones and laptops. The actors were chosen based on the information gathered from interviews and from literature review. During the interviews, the interviewees were asked to nominate the key actors that might help to extend the lifetime of smartphones and laptops. The interviewees highlighted what actors could overcome the barriers to extending the lifetime of smartphones and laptops.

The table below provides an overview of the actors and gives some examples of how each actor can contribute to extending the lifetime of smartphones and laptops.

Focus of this study

Actors	How they can help extending the lifetime of smartphones and laptops (examples)
Policy makers	**"***Policy makers are a very strong actor able to provide correct guidelines and requirements for longevity of products***" (***Angouria-Tsorochidou, 2021)* Policy makers could ensure that the consumers have information regarding repairability (Oldyrevas, 2021) They could create incentives to encourage users to repair (reduced VAT on repair services) (EEB, 2019) Setting requirements on design for disassembly (EEB,2019)

Manufacturers	"*Some actions are possible through operation supply chain actors, in software specifically Google they said that they will provide Android updates for three years, that has a push and a direct impact on how much individual phone manufacturers will provide the security and firmware updates for" (Oldyrevas, 2021)* Design products for durability, modularity, repairability and upgradability (EEB, 2019)
Repair companies	Through repairing, the lifetime of the products is extended.
Consumers	The consumers can contribute to ensure that the products last longer, by choosing whenever possible high-quality products, by following the manufacturer's instructions on how to make the product last longer (EEB, 2019)
Activists	For example, the members of the European Right to Repair campaign are advocating for a universal Right to Repair which will contribute to **lasting products**, **access to accessible spare parts** as well as **repair manuals**, **information on product repairability** (Right to Repair, 2020b)
Researchers	The researchers could play a role if they will focus also on sustainability aspects not only on innovation aimed at functionality improvements alone (Oldyrevas, 2021)

Table 2 Actors who can contribute to the lifetime extension of smartphones and laptops

This study intends to investigate what measures could be taken by the **EU**, through **policy intervention** to address the issue of lifetime extension of smartphones and laptops.

As Angouria Tsorochidou (2021)-the Board Member of Repair Café Denmark explained, "*It is **currently** impossible to disconnect the economic benefits from the environmental degradation*" and "*it is **rare** that companies will try to reduce environmental impact"* without regulation, subsidies, or other measures.

The next section will present therefore, what are the instruments available at the EU level which might help to address the lifetime extension of the products under investigation.

3.2. Instruments available at the EU level to address the lifetime extension of the consumer electronic products

This sub section will present information about the instruments available at the EU level, which might support the lifetime extension of the consumer electronic products, with a focus on smartphones and laptops.

3.2.1. Overview of the instruments

The table 3 below presents the main instruments available at the EU level which can address the lifetime extension of the consumer electronic products. The instruments were classified based on the "Better Regulation Toolbox 18" from the European Commission website. According to the tool 18 "The choice of policy instruments", the policy instruments at the EU level can be broadly categorized into: "hard legally binding rules", "soft regulation", "education and information" and "economic instruments" (European Commission, 2021d). A short description of the instruments is presented in the next chapters. The instruments relate to the case studies investigated, namely smartphones and laptops.

Legislation Ecodesign Directive, Energy Labelling
Voluntary instruments Green Public Procurement, EU Ecolabel
Strategies Circular Economy Action Plan
Economic instruments **-**

Table3: Overview of the instruments available at the EU level to address the lifetime extension of consumer electronics-based on Better Regulation Toolbox 18 (European Commission, 2021d)

3.2.1.1 Legislation

Ecodesign Directive

The Ecodesign Directive 2009/125/EC of the European Commission provides a framework for the setting of ecodesign requirements for the energy related-products to protect the environment by minimizing the potential environmental impact of the energy-related products(European Commission 2009).The **Ecodesign Directive** sets **mandatory minimum requirements** for the environmental performance of the products and therefore is removing the worst performing products on the market (Huulgaard and Remmen, 2012).The manufacturers have to fulfil minimum energy efficiency requirements and environmental criteria such as emission levels, water consumption or minimum durability of certain components before placing their products on the market(Vidal-abarca, Dodd, and Wolf 2020)

On October 1st 2019, the European Commission has adopted new ecodesign measures for ten products: washing machines and washer-driers, dishwashers, electronic displays, household refrigerators, light sources, refrigerators with a direct sales function, external power supplies, electric motors, power transformers, welding equipment ((Mathieux, Ardente, and Bobba 2020; Bachér et al. 2020). The new ecodesign measures includes for the first time **requirements for repairability and recyclability**, aiming to **improve lifespans**, maintenance, reuse, upgrades and therefore to contribute to circular economy objectives (Bachér et al. 2020). On 1 March 2021, the changed ecodesign rules came into force for the washing machines, fridges and freezers, dishwashers, and electronic displays (European Commission, 2021a). The new measures include requirements which helps to enhance the reparability and recyclability of the products. Such requirements refers to making spare parts more easily replaceable and to providing key parts and information regarding repair and maintenance for end users and professional repairers for minimum 7-10 years, depending on the product (European Commission, 2021a)

To increase the lifetime and improve the sustainability of smartphones and laptops, the Ecodesign framework is the most suitable approach (Right to Repair, 2020a). However, the 2016-2019 Ecodesign Working Plan has not led to any regulatory action for smartphones and other ICT products (Right to Repair, 2020a). More than that, the new EU Ecodesign measures which came into force in March 2021 are also excluding the smartphones and laptops, even though they are affected by premature obsolescence and discarded prematurely (Right to Repair, 2020a).

Energy Labelling

The Ecodesign Directive is complemented by the Energy Labelling Framework Regulation EU 2017/1369 which establishes a framework for the "*provision of accurate, relevant and comparable information on the specific energy consumption of energy-related products*" and "*enables customers to make informed choices based on the energy consumption of energy-related products*" (European Commission, 2017). While the Ecodesign Directive "*pushes the market upwards from minimum requirements*", the Energy Labelling "*pulls the market towards best practice technologies*"(Boyano Larriba, Espinosa Martínez, and Villanueva Krizyzaniak, 2017)

In addition to the new ecodesign rules, new energy labelling rules have been introduced starting with 1 March 2021for four product categories: fridges and freezers, dishwashers, washing machines and television sets (European Commission, 2021a). The product categories mentioned will undergo a rescaling under which A+, A++, A+++ will be adjusted to reintroduce a simpler A to G scale (European Commission,2021a; Bachér et al. 2020). The most energy efficient product at the moment on the market will now be labelled as "B", "C" or "D", while very few products will be able to achieve the "A" rating (European Commission, 2021a). A new element to be included on the labels is a QR link to an EU-wide database, making possible for the consumers to discover more information about the product (European Commission, 2021a).

There are 15 product groups which require an energy label such as fridges and freezers, washing machines and washer-dryers, air conditioners and comfort fans (European Commission, 2021c). There are no energy label for laptops or smartphones. However, on March 2019 was adopted the Commission Delegated Regulation EU 2019/2013 regarding the energy labelling of electronic displays which repeals and replace the Regulation EU 1062/2010 regarding the energy labelling of televisions (European Commission, 2019a). The Regulation establishes requirements for the labelling of electronic displays, including televisions, monitors (computer monitor or computer display) and digital signage displays (European Commission, 2019a). As mentioned above, an Ecodesign Regulation for electronic displays was adopted (EU 2019/2021) (European Commission 2019c). This Regulation sets minimum mandatory requirements for all manufacturers and importers placing products on the EU market and includes elements to improve reparability (European Commission, 2019c)

3.2.1.2 Voluntary instruments

Green Public Procurement

In Europe, the public authorities can use their purchasing power and contribute to sustainable consumption and production by choosing environmentally friendly products, services and works through what it is called the Green Public Procurement (GPP) or green purchasing (European Commission, 2021b). GPP is a **voluntary instrument** and has an important role in EU's effort to achieve a more resource-efficient economy (European Commission, 2021b). In March 2021, the European Commission published new voluntary EU GPP criteria for computers, smartphones, tablets, and monitors (European Commission, 2021b). The criteria are aiming to address the main environmental impacts of these devices and are divided into four distinct categories: "*product lifetime extension, energy consumption, hazardous substances, end-of life-management"* (European Commission, 2021b)

The table 4 below is presenting only the "product lifetime extension" criteria for mobile computers and smartphones. The product lifetime extension criteria is divided into 4 categories: *Reparability, reusability, and upgradability, Rechargeable battery life and endurance, Mobile equipment durability testing and Interoperability and reusability of components* (European Commission, 2021b). For each category, the technical specifications to be fulfilled by the tenderers are presented, as well as which criteria apply to which product group.

Type of criterion	Criterion	Mobile computers	Smartphones
Product lifetime extension			
Reparability, reusability, and upgradability			
Technical specifications	Provision of an extended service agreement	**X**	**X**
	Continued availability of spare parts	**X**	**X**
	Manufacturer's warranty	**X**	**X**

	Design for reparability	**X**	**X**
	Functionality for secure data deletion	**X**	**X**
Rechargeable battery life and endurance			
Technical specifications	Rechargeable battery endurance	**X**	**X**
	Minimum requirements for electrical performance	**X**	**X**
	Information on battery state of health	**X**	**X**
	Battery protection software	**X**	**N.A.**
	Intelligent charging	**N.A.**	**X**
Mobile equipment durability testing			
Technical Specifications	Drop testing	**X**	**X**
	Temperature stress	**X**	**X**
	Ingress protection level – semi-rugged and rugged devices	**X**	**X**
Interoperability and reusability of components			
Technical specifications	Standardized port	**X**	**X**
	Standardized external power supply	**X**	**X**
Technical specifications	External power supply: detachable cables	**X**	**X**
	Backward compatibility: adapters	**X**	**N.A.**

Table 4: Criteria structure and applicability for mobile computers and smartphones-based on(European Commission, 2021b)

EU Ecolabel

The ecolabels set criteria which can be fulfilled only by the **best products** on the market, therefore pushing the market towards more **environmentally friendly** products (Huulgaard and Remmen 2012).

The EU Ecolabel is a voluntary scheme that awards products and services meeting the best environmental performance throughout their life-cycle (Vidal-abarca, Dodd, and Wolf 2020). The Eu Ecolabel criteria provides exigent requirements, higher than those included in the Ecodesign and as least as highest as the ones of the EU Green Public Procurement(Vidal-abarca, Dodd, and Wolf 2020) (see figure 4 below)

The EU Ecolabel does not have criteria for smartphones or laptops.

In November 2020 a revised EU Ecolabel criteria for electronic displays was introduced (European Commission, 2020a). The new EU Ecolabel criteria aim "*promoting products that are energy efficient, repairable, easy to dismantle (in order to facilitate the recovery of resources from recycling at the end of their useful life), have a minimum recycled content and which may only contain a limited amount of hazardous substances*" (European Commission, 2020a)

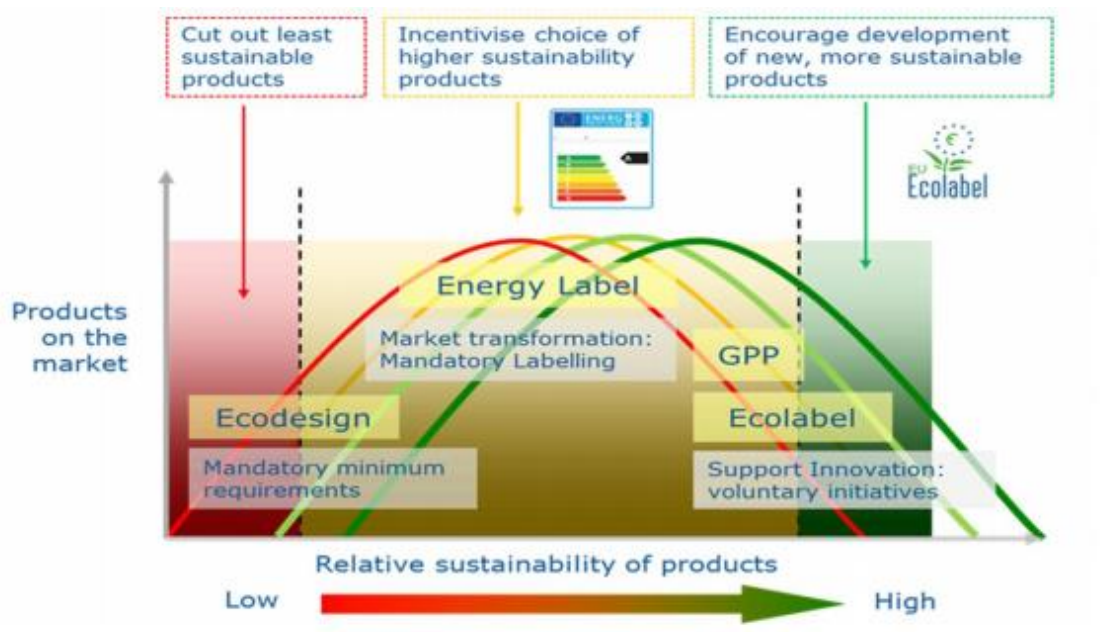

Figure 4 Synergies between the Ecodesign, Energy Label, GPP, Ecolabel (Vidal-abarca, Dodd, and Wolf 2020)

3.2.1.3 Strategies

Circular Economy Action Plan

Lately, the product lifetime extension is a very actual problem, many initiatives being taken in this direction. In Europe, the European Commission launched in 2019 the "European Green Deal" (European Commission, 2019b). The "European Green Deal" of the European Commission highlights the importance of resource-efficiency. The main goal of the "European Green Deal" is to reach the target of climate neutrality by 2050, making Europe the first climate-neutral continent (European Commission, 2019b). On the European Green Deal agenda, a main initiative for sustainable growth was to adopt a new Circular Economy Action Plan (European Commission, 2019b). The key aspects discussed within the new Circular Economy Action Plan are related to the sustainable products, meaning that the aim is to:

-improve product durability, reparability, reusability, and upgradability

-enhance recycled content in products

-enabling remanufacturing

-reducing the environmental footprints

-countering the premature obsolescence

(European Commission, 2020b)

Moreover, this Action Plan gives priority to address product groups such as electronics, ICT, and textiles (European Commission, 2020b)

The new Circular Economy Action Plan provides initiatives for priority sectors and value chains to enhance circularity. This is the case of electronics and ICT (European Commission, 2020b). The Circular Economy Action Plan provides a set of actions to be taken to address the challenges within the electronic and ICT sector. The main actions are:

-to promote longer product lifetimes

-regulatory measures under the Ecodesign Directive to design for energy efficiency and durability, maintenance, reuse and recycling, and upgradability the electronic and ICT (including laptops and mobile phones) devices

-regulatory measures for mobile charges, enhancing the durability of charging cables, the introduction of a common charger

-setting the ICT and electronics as a priority sector to apply “the right to repair”

-finding options for a broad EU take-back scheme to sell back or return old mobile phones, chargers, and tablets

(European Commission, 2020b)

An initiative of the Circular Economy Action Plan is **The Sustainable Products Initiative**, planned for announcement in the fourth quarter 2021 will set rules to make ICT equipment and electronics more sustainable (NGI Forward, 2021). Another part of the Circular Economy Plan is the **Circular Electronics Initiative** also planned for unveiled in the fourth quarter 2021. The intention is to set regulatory measures for ICT products including laptops and smartphones, under the Ecodesign Directive (NGI Forward, 2021). The Circular Electronic Initiative will implement a right to repair, a right to update obsolete software, measures on a common charger, measures on improvements of collection and waste management of electronics and a review of EU rules regarding hazardous substances in EEE (NGI Forward, 2021; European Commission, 2020b)

4. Scope

4.1. Aim of the research

As explained in the 3.1.2. section, it is of a great importance to extend the lifetime of smartphones and laptops. Smartphones and laptops were chosen as the object of interest in the project because compared with other consumer electronics they have a much shorter lifetime (as it was presented in the section 3.1.2.) and because they have high environmental impacts, mostly resulting from the production stage (as it was presented in the 3.1.2. section). The lifetime extension of smartphones and laptops is investigated in the European context. Even though there is a necessity to extend the lifetime of smartphones and laptops, there are some barriers that prevent this to happen. The purpose of this study is to identify the main measures that could be adopted by the European Union (EU) to stop the barriers and as a result, to help extending the lifetime of smartphones and laptops.

4.2 Research question

The main research question will explore: *How can European Union (EU) break down the barriers to extending the lifetime of smartphones and laptops?*

Sub-Questions:

To provide a comprehensive answer to the research question, the following sub-questions have been identified as important to be answered:

1. What are the environmental impacts caused by the smartphones and laptops?
2. What are the main barriers to extending the lifetime of smartphones and laptops?
3. What are the main possible measures that EU could adopt to help extending the lifetime of smartphones and laptops?

An explanation of the importance of those sub-questions and how they help answer the research question is provided in the chapter 6., the Data analysis section. Moreover, an overview of the thesis research design is provided below.

4.3 Research design

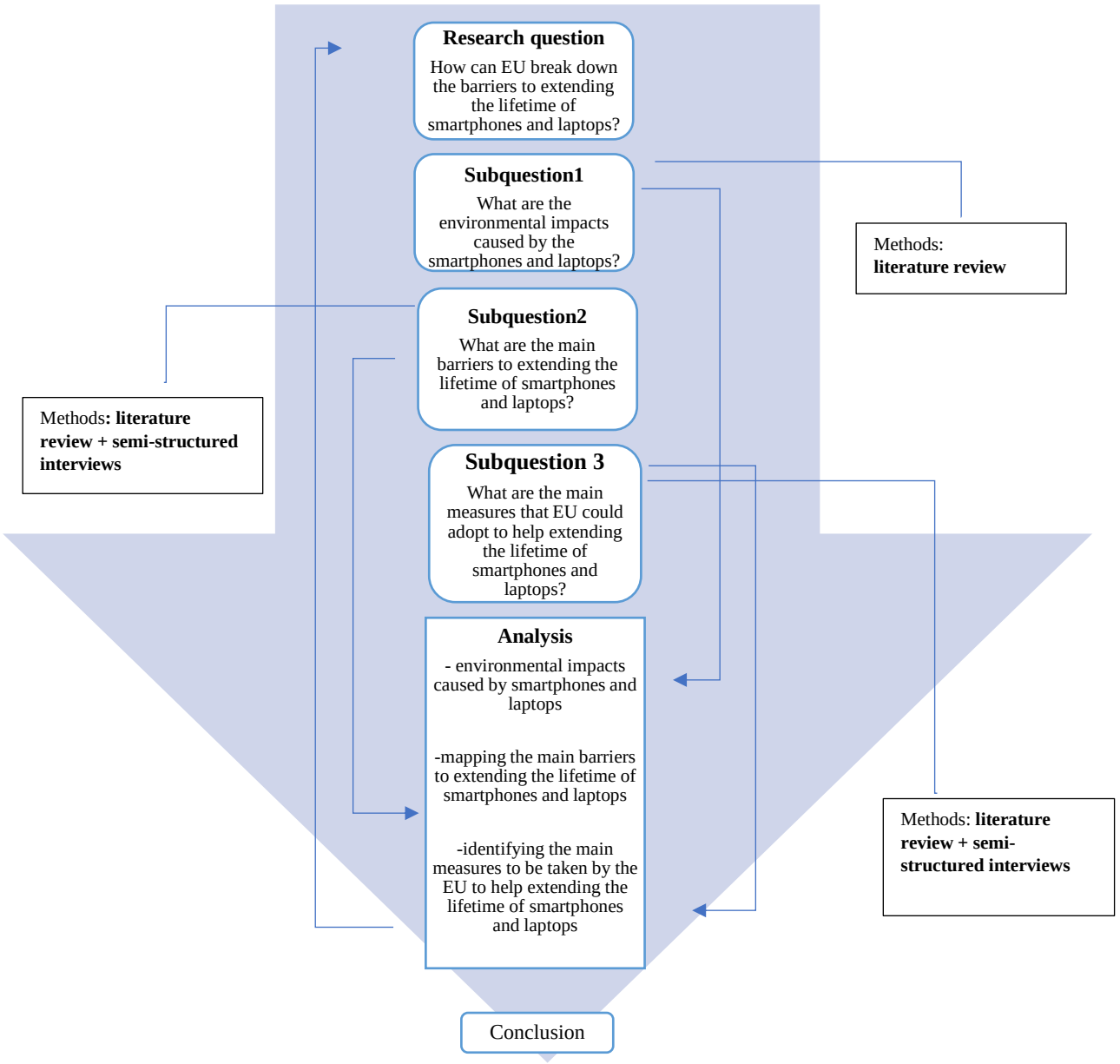

Figure 5 Research design overview

5. Methodology

5.1. Research philosophy and research approach

The **research approach** used in this study is the abductive approach. Abductive approach is a process used to explain a surprising fact(Folger and Stein 2017). The puzzling situation in this research is that even though there is a necessity to extend the lifetime of smartphones and laptops, there are some barriers that hinder this to happen. Abductive reasoning which is also corresponding with "inference of the best explanation" (Folger and Stein 2017) will be used to infer what measures might be taken by the EU to address the barriers to extending the lifetime of the products under research.

Even though Aristotle was the first author to discuss abduction, the author who coined the term was Charles Peirce(Folger and Stein 2017). Charles Peirce introduced three types of reasoning: deductive, inductive and abductive (Cramer-Petersen, Christensen, and Ahmed-Kristensen 2019). Abductive reasoning involves guessing hypotheses as the basis for reasoning (Cramer-Petersen, Christensen, and Ahmed-Kristensen 2019).

Regarding the **research philosophy**, this research shows components of interpretivism. According to Saunders, Lewis, and Thornhill (2013) crucial to the interpretivist philosophy is "*to enter the social world of our research subjects and understand their world from their point of view*". Moreover, interpretivism comes "*from two intellectual traditions: phenomenology and symbolic interactionism*" (Saunders, Lewis, and Thornhill 2013). The way in which "*humans make sense of the world around them"* is phenomenology, while symbolic interactionism refers to "*interpreting the social world around us"* (Saunders, Lewis, and Thornhill 2013). In this study interpretivism appears in the use of interviews and how the interviewees perceive and interpret the social world around them (for example the barriers for extending the lifetime of smartphones and laptops).

As a **research strategy**, this study is using case study. This research is based on two case study: smartphones and laptops. According to Flyvbjerg (2006) a strategy for the selection of samples and cases is to find extreme/deviant cases. The purpose of using this case selection is "*To obtain information on unusual cases which can be especially problematic or especially good in a more closely defined sense*"(Flyvbjerg, 2006)

Smartphones and laptops can be considered extreme cases because as explained in the 4.1 section these products have much shorter lifetimes than other consumer electronic products and because in their case, the environmental impacts are resulting mostly from the production phase.

5.2. Data collection

For this research paper, the data was collected from mixed methods, using qualitative data as well as quantitative information The quantitative information come from secondary sources in terms of, for example data regarding the CO_2 emissions. The quantitative data is more present in the first sub-question which investigates the environmental impacts caused by the smartphones and laptops. The qualitative data are based on the literature review and semi-structured interviews. Qualitative data is more present in the second and third sub-questions.

5.2.1. Literature review

The literature review was used to gather information needed to provide the framework for the study (section 3 of the research) and to answer research question and sub-questions.

To have actual and updated information regarding the topic of this research, the most recent articles, reports, studies were investigated. The research was done using databases such as: Science Direct, Web of Science, Google Scholar. Furthermore, the website of the European Commission was used to gather information of the European Commission laws and publications. Moreover, reports from: European Environmental Bureau (EEB), Environmental Coalition on Standards (ECOS)and NGI Forward were used to gather information.

To find information regarding the barriers that prevent the lifetime extension of the products under investigation and information on the measures that might be adopted at the EU level for addressing this, the following articles and reports were used: Rizos et al. (2019), Cordella et al. (2021), NGI Forward, (2021), ECOS, (2020), Cordella, Alfieri, and Sanfelix (2020), Bachér et al.(2020).

5.2.2 Semi-structured interviews

In qualitative research there are different types of interviews such as: unstructured, semi-structured and structured (Baumbusch 2010). Semi-structured interviews involve open-ended questions allowing for spontaneous responses(Baumbusch 2010; DiCicco-Bloom and Crabtree 2006).

All the semi-structured interviews were conducted in English and were recorded. All interviewees were asked permission to record the interview, and all agreed. To ensure accuracy, the interviews were summarized and made available to the persons interviewee. The purpose was to ensure that the information to be included from each interview is correct and that it can be included in the thesis. The interviews guidelines are presented in the Appendix.

The purpose of conducting the interviews was to find out the viewpoint of the experts (each interviewee can be called expert in their field), within different fields related to smartphones and laptops, regarding on the one hand the barriers to extending the lifetime of smartphones and laptops, and on the other hand, regarding the measures that might be adopted at the EU level to address the barriers (as you can see in the table 5 below).

Interviewee	**Organization**	**Role in the organization**	**The purpose of the interview was to find information regarding**	**How was the interview conducted**
Philip Douglass	Fair Denmark	Board of Directors	-the barriers to extending the lifetime of **laptops** - what measures could be taken by the EU to address the situation	-by phone
Martin Mørch	iPhone Repair	Company manager	-the barriers to extending the lifetime of **iPhones**	-by phone
Ernestas Oldyrevas	ECOS	Programme manager	-the barriers to extending the lifetime of **smartphones** and **laptops** -what measures could be taken by the EU to address the situation	-through Microsoft Teams

Michael Søgaard Jørgensen	Aalborg University, Copenhagen	Associate Professor, Department of Planning	-the barriers to extending the lifetime of **smartphones** and **laptops** - what measures could be taken by the EU to address the situation	-by phone
Elisavet Angouria Tsorochidou	Repair Café Denmark	Board member	-the barriers to extending the lifetime of **smartphones** and **laptops** - what measures could be taken by the EU to address the situation	-by phone

Table 5. Overview of the interviews conducted

A short introduction of each of the interviewee is provided below.

Philip Douglass is on the Board of Directors at Fair Denmark and has strong knowledge of computer engineering (Ph.D. power and computer engineering). Fair Denmark is a voluntary and unpaid association, based in Copenhagen, Denmark, that provides IT equipment to Malawi, to ensure access to information technology for students (FAIR Denmark, 2021). Fair Denmark collects used IT products, which are then prepared for a new life, through repair and refurbishment and afterwards the products are donated to Malawi (FAIR Denmark, 2021). The key activity of FAIR is refurbishment of computers and laptops (FAIR Denmark, 2021)

Martin Mørch is the director and the owner of the iPhone Repair, a repair shop located in Esbjerg, Denmark. He provided useful information regarding the topic of the research as at the iPhone Repair they are repairing iPhones and iPads.

Ernestas Oldyrevas is a Programme Manager at ECOS, a network of environmental NGOs, advocating for ambitious policies and standards, predominantly in Europe, but also globally (Oldyrevas, 2021). Ernestas works in the Climate and Energy team, more exactly in the subsection focusing on ecodesign and European Product Policy. He is focusing on the ecodesign of ICT products in terms of regulatory requirements and supporting standards (Oldyrevas, 2021) The interview was truly relevant as the purpose of the project was to investigate what are the barriers that hinder the lifetime extension of smartphones and laptops but also what measures could be adopted at the EU level, to address the situation.

Michael Søgaard Jørgensen is Associate Professor at the Department of Planning, Aalborg University, Copenhagen, his field is Sustainable Innovation, and he works with concepts such as Circular economy and extending the lifetime of products (Jørgensen, 2021). The interview conducted with Michael Søgaard Jørgensen provided useful information regarding the topic of the research.

Elisavet Angouria-Tsorochidou is a board member at Repair Café Denmark since 2018. The Repair Café Denmark is an organization created in 2018 with the purpose of representing all the repair cafes in Denmark aiming to help find volunteers, helping find funding and trying to positively affect regulation and policy at the national and international level, e.g., by being in collaboration with the Right to repair movement (Angouria-Tsorochidou, 2021). The repair cafes differ from the repair shops. "*The repair cafes are not open daily, and they are not even often open actually, usually once per month, or in rare cases once a week. They are* ***volunteer based organizations*** *so no one is getting paid. Besides we both repair things, I do not see any major similarities between repair shops and repair cafes" (Angouria-Tsorochidou, 2021).* According to Angouria-Tsorochidou (2021), the purpose of the repair cafes is to show people that they can repair their own items, that the repair is possible.

6. Data analysis

To help answering the research question, three sub-questions have been formulated, each of them having a specific role. The sub-questions, as mentioned in the 4.2, are:

1. What are the environmental impacts caused by the smartphones and laptops?
2. What are the main barriers to extending the lifetime of smartphones and laptops?
3. What are the main possible measures that EU could adopt to help extending the lifetime of smartphones and laptops?

6.1 What are the environmental impacts caused by smartphones and laptops?

The first sub-question helps to have a better understanding of the environmental impacts caused by the smartphones and laptops and emphasize the benefits of extending their lifetimes. The purpose is to provide evidence that extending the lifetime of the products under investigation is more environmentally friendly than producing new ones and therefore it is important to break down the barriers that hinder the lifetime extension.

The environmental impacts of smartphones and laptops have been analysed and discussed through different studies (Tecchio et al. 2018). In the smartphone and laptop case, the environmental impact over the lifetime is largely attributed to the production phase (Rizos et al. 2019; EEB 2019).

In the study conducted by (Rizos et al. 2019) it is estimated that for an average mobile phone 81% of the CO_2 equivalent footprint is represented by the production phase which includes the extraction of the raw materials, their processing as well as the production and assembly of the components. To manufacture a smartphone of about 129 g, is needed to be mined a rock of about 34 kg, which means that the amount of mining required to produce a smartphone exceeds by 260 times the material used in a smartphone (Rizos et al., 2019) Moreover, the environmental impacts from the extraction cover the CO_2 equivalent emissions from extraction and processing phase as well as the environmental impact caused by the creation of pollution and waste by mining and digging the earth. For example, copper mining requires high amount of energy, can create air pollution and produce polluted waste (Rizos et al. 2019)

The study conducted by(Hischier and Böni 2021) showed that products devices such as smartphones or laptop computers whose dominant environmental impact is in their production, should be reused independently of their age, whereas for other products such as washing machines, televisions and refrigerators, age is a decisive factor.

The production of new mobile phones leads to releasing greenhouse gases into the atmosphere which contributes to the climate change(Manivannan 2016). Mobile phones can cause high environmental impacts due to their heavy metal content such as copper, lead, arsenic and mercury(Manivannan 2016). As new models become available every year, changing the mobile phones create unnecessary carbon footprint and hazardous waste (Manivannan 2016). Moreover, improper disposal of waste mobile phones can cause environmental degradation in developing countries(Manivannan 2016)

The study conducted by Öko-Institut (2012) revealed that the overall greenhouse gas emissions attributable to an average notebook with a useful lifetime of 5 years are between 230 and 382 kg CO_2 equivalent. This depends upon the data source utilized to calculate emission from the production stage of a notebook (Öko-Institut, 2012). They have also analysed the environmental amortization period to determine the environmentally most favorable periods for the utilization or replacement of a notebook (Öko-Institut, 2012). The results shoved that the environmental impact caused by the production of a notebook cannot be compensated in a realistic period, even with an improved energy efficiency during the use phase (Öko-Institut, 2012)

In the table 6 below is presented the climate impact of smartphones and notebooks and the benefits of extending their lifetime by 1, 2 or 5 years. The information are based on the (EEB, 2019) study.

	SMARTPHONES	NOTEBOOKS
Annual climate impact of EU stock (use and non-use phases)	14,12 million tonnes of CO_2 equivalent	12,82 million tonnes of CO_2 equivalent
Manufacturing, distribution, and disposal account for about:	72% -of a smartphone's total climate impact	52 % -of a notebook's total climate impact
Expected lifetime	3 years	4,5 years
Annual sales	210.800.000 units	27.602.000 units
Total stock in the EU	632.400.000 units	151.085.000 units
Extending the lifetime of all smartphones/notebooks in the EU by:		
1 year:	-would save 2,1 Mt CO_2 per year by 2030, the equivalent of tacking over a million cars off the roads	-would save 1,6 Mt CO_2 per year by 2030, the equivalent of tacking over 870.000 cars off the roads
2 years	-would save around 4,3 Mt CO_2 annually by 2030	-would save around 3,7 Mt CO_2, annually by 2030
5 years	-would save about 5,5 Mt CO_2 annually by 2030	-would save about 5Mt CO_2, annually by 2030

Table 6. Climate impact of smartphones and notebooks and the benefits of extending their lifetime – based on (EEB 2019)

6.1.1. Conclusion

This section has analyzed the environmental impacts caused by smartphones and laptops. The findings of this section showed that the environmental impacts of smartphones and laptops are caused mostly by the production phase. The production of these devices involves greenhouse gases emissions which contribute to the climate change. The findings also showed that laptops and smartphones should be reused independently of their age (Hischier and Böni, 2021). Moreover, extending the lifetime of all smartphones/notebooks in the EU by 1, 2 or 5 years showed great potential environmental savings.

6.2 What are the main barriers to extending the lifetime of smartphones and laptops?

To find out the solutions to break down the barriers to extending the lifetime of smartphones and laptops it is important to know what the main barriers are. This section aims to provide information regarding the problems that prevent the lifetime extension of smartphones and laptops. The data were collected using literature review and semi-structured interviews.

6.2.1 Findings from literature review

Legislative issues

Several studies have examined the factors that prevent lifetime extension of mobile phones and laptops. According to the Rizos et al. (2019) study, the barriers to extend the lifetime of mobile phones in Europe are mainly related with the EU legislation. Specifically, the two-year minimum legal guarantee for new products set by the Consumer Sale Directive affects the repair service and second-hand refurbishment markets (Rizos et al., 2019). Another challenge identified refers to the lack of clarity regarding the refurbished products from outside the EU which already bear the CE marking in the new condition. According to the EU legislation, the products coming from outside the EU must bear the CE marking and the manufacturer must sign a Declaration of Conformity stipulating that the products are conform with the legal requirements (Rizos et al. 2019). According with the study, it was suggested that for refurbished mobile phones which have undergone only small alterations without changing the performance of the product, the company should not present a new Declaration of Conformity, even if the product are imported from countries outside the EU (Rizos et al. 2019)

Software and firmware issues

To operate properly and be protected against security threats, smartphones require regular software updates (NGI Forward, 2021). However, after two or three years, most of the smartphones stop receiving updates which can lead to shortening the lifetime of smartphones (NGI Forward, 2021). Moreover, specific applications can also stop being compatible with older versions of software, leading to popular applications such as WhatsApp to become unavailable to users of older

smartphones (NGI Forward, 2021). The functional lifetime of smartphones is related with the software/firmware supporting period provided by the manufacturers (Cordella et al. 2021).Although the lack of operating system updates does not bring immediate failure, in the long term can affect the performance of the installed applications, due to loss of security (Cordella et al. 2021). Moreover, insufficient memory capacity in the device could cause issues for the installation of software and firmware updates, and therefore creating difficulties in using the smartphone(Cordella et al. 2021).

The latest operating systems and new programmes are affecting the performance of older laptops (ECOS, 2020). This will slow down the devices over time until they will not be able to function properly (ECOS, 2020). Firmware is co-developed with the device itself and cannot be attained from any alternative provider (ECOS, 2020). The manufacturer must provide firmware updates and ensure that the product is functioning as sold (ECOS, 2020)

Lack of repair information

Digital devices are frequently complex and need accurate manuals for their repair (NGI Forward, 2021). The manufacturers are closely monitoring the access to information about how to repair their devices, making difficult for repairers and users to extend the lifetime of their products (NGI Forward, 2021). Consumers and many repair professionals are prevented from conducting the most common repairs due to a lack of reliable public information (NGI Forward, 2021)

Deficient robustness

Smartphones are easily replaced with new devices, after a short period of time, due to loss of performance, failures and breakages (Cordella et al. 2021). The results of a consumer survey showed that the frequency of failures in smartphones can be relatively high compared with other devices and that the highest number of problems was attributed to battery and operating system(Cordella et al. 2021). Moreover, according to Cordella et al. (2021) the main affected parts of smartphones are: display, back cover, battery, operating system. Most modern smartphones feature a glass display and an increasing number of devices come with glass on the back(Cordella

et al. 2021). Even though the glass is relatively more scratch-resistant than plastics, the main disadvantage is represented by the fragility of the material (Cordella et al. 2021). Over time and with use, all rechargeable batteries are degrading, resulting in a loss of performance(Cordella et al. 2021). The lifetime of battery is an important aspect in a smartphone, and a long battery lifetime can delay the replacing of the device(Cordella et al. 2021)

According to ECOS (2020) report the failures regarding the laptops are due to hardware malfunction and accidental damages. Some laptop models have major weaknesses when it comes to resistance to shock or water contact (ECOS, 2020). Insufficient battery performance, problems related to computer screens, keyboards, chargers, and hard disk drivers can lead to premature replacement of laptops (ECOS, 2020). Better design can reduce the occurrence of this kind of failures (ECOS, 2020)

Difficulty to repair

The lack of spare parts and the high cost of repair can represent an obstacle to repair the smartphones(Cordella et al. 2021). Depending on the involved parts, labor cost, and design choices, the cost of repair can vary significantly. For example, repairing the display of the smartphone could involve a cost of about 15-40% of the purchase price of new device (Cordella et al. 2021). Another barrier to repair is represented by the difficulty to disassemble and reassemble parts of device, such as batteries and displays (Cordella et al. 2021). iFixit (2019) created a platform which provides information regarding repair of the smartphones (Cordella et al. 2021). Besides the instruction regarding the repair, this platform provides a repairability score for a number of smartphones models (Cordella et al. 2021). According to (Cordella, Alfieri, and Sanfelix 2020), the worst 10% devices in terms of repairability were characterized by:

-high difficulty to open the back cover case and accessing the parts
-the disassembling process difficult due to intensive use of adhesive
-difficulty in replacing the battery
(Cordella, Alfieri, and Sanfelix 2020)
Recent models of smartphones have the batterie fastened within the phones with adhesives and the removal of batteries requires intervention from experienced repairers (Cordella et al. 2021)

The potential to repair the laptops is often influenced by the labor cost which is lower the more modular the design (ECOS, 2020). Innovative designs can be at the same time lightweight and modular to facilitate repair, however lightweight solutions are often achieved through integrated designs (ECOS, 2020). This approach can lead to prematurely discarded devices due to difficulty and high cost of repair (ECOS, 2020). Other issues which can prevent the repair of laptops, refers to unavailability of spare parts or the high cost of the spare parts, the difficulty in accessing the spare parts, the fact that the labor time required for repair results in prohibitive costs (ECOS, 2020)

Users concern regarding privacy data

Many laptop users choose to store old laptops due to privacy concern regarding personal data. This approach prevents laptops of being reused (ECOS, 2020). The fact that the laptops do not have an easy way to erase and reset data is an important reason for the users to deny the laptops a second life (ECOS, 2020). Moreover, if the users discard their items without implementing a factory reset can represent an obstacle to computer remanufacture (ECOS, 2020). This is because some device enrolment systems (such as Apple's iCloud) either do not allow BIOS passwords to be changed, or do not allow a reset by a third party (ECOS, 2020)

6.2.2 Findings from the interviews

The following section will present the findings from the interviews, regarding the barriers to extending the lifetime of smartphones and laptops.

Difficulty in accessing the spare parts

According to Oldyrevas (2021), one of the barriers to extending the lifetime of smartphones and laptops is related to the difficulty in accessing the spare parts.

This issue was pointed out also by Martin Mørch, mentioning the fact that Apple does not sell spare parts. "*They try to limit the possibility for the consumers to get their electronics repaired because if you want original parts for your phone, you have to contact Apple, ship to Apple to get the phone repaired, or buy new phone"* argued Mørch (2021).

Regarding the obstacles faced when refurbishing a laptop, Douglass (2021) mentioned that the main issue is related with the laptop's keyboard. The keyboards are often damaged and finding

spare parts for them is difficult because the spare parts are unique for every laptop model. This problem is not encountered in the desktop computers case where there are standard keyboards which can be easily switched around (Douglass, 2021).

One of the barriers to extending the lifetime of smartphones and laptops mentioned by Angouria-Tsorochidou (2021) is related to the lack of spare parts.

Lack of information on repairability of the devices

The consumers do not have information on the repairability of their devices (Oldyrevas, 2021) According to Oldyrevas (2021) "*Unless you are a technical expert or somebody who is willing to spend enormous time on the internet…it is difficult for you to choose a device that will be easy to repair later on"*

Software and hardware issues

Some firmware, security and software updates have a high impact on the longevity of the devices. Smartphones, for example do not have an easy way to return to the previous version of the operating system and this is affecting their functional performance (Oldyrevas, 2021)

Regarding the barriers for extending the lifetime of smartphones and laptops, **Jørgensen** (2021) mentioned the **functional obsolescence**. He argued that this occurs due to the software development which is constantly evolving. This indicates that for example in the laptop case, there is a need to update the software system once this becomes outdated, because "*software is developed in a way that might not work with older laptops*" (Jørgensen, 2021)

Jørgensen (2021) explained that is not impossible to extend the lifetime of laptops and that can be done by installing new software. "*We have a company Refurb, and they are extending the lifetime of laptops by installing new software and then selling the laptops as used laptops with a full warranty*" specified Jørgensen (2021)

According to **Mørch** (2021) the iPhones are easily replaced, after a short period of time, by the consumers due to a hardware issue-the motherboard is becoming too slow. "*That is why people are buying new phones because the phone is becoming too slow*" (Mørch, 2021) Another issue related to the short lifespan of iPhones is due to the fact that Apple stops updating the software

which makes impossible to install new applications because the phone is too outdated (Mørch, 2021)

The main issue that prevents laptops to have a longer life is related to the software which over time becomes outdated, resulting in the old laptops to be useless (Douglass, 2021).

To extend the lifetime of laptops **Douglass** (2021) pointed out that is more a question of software and how is being used and suggested that the people who make software services should ensure that that the software will continue to be accessible from older laptops.

Another barrier mentioned by **Angouria-Tsorochidou** (2021) refers to the impossibility of updating the software of the mobile phones.

Difficulty in repairing the products

The increasing use of serialization (linking spare sparts to the device and not being able to replace parts of the device if they are not from the same model) makes the repair process difficult (Oldyrevas, 2021)

Regarding the obstacles that they are facing when repairing an iPhone, Mørch (2021) explained that "*The biggest obstacle is that Apple tries to stop the independent repair shops to repair the iPhones, they created something called software lock where if you change the screen of the iPhone, then the iPhone will inform the consumer that this is not a genuine screen from Apple".*

The fact that the phones and laptops have parts that are glued together, makes the repair process difficult (Angouria-Tsorochidou, 2021)

The cost of the repair

The fact that spare parts are bundled together results in making the reparability of the devices very costly. "*If your USB connector broke but then you are told to replace an assembly which includes a whole set of additional components, ...you will have to pay an outsized chunk of the total price of the product" (Oldyrevas, 2021)*

Many times, is even more expensive to repair a laptop than to buy a new one (Angouria-Tsorochidou, 2021)

Durability issues

A huge problem mentioned by Mørch, (2021) was also the fact that the phone battery must be replaced after a short period of time. "*Even new iPhones they maybe have to have the battery replaced after 1-2 years"* (Mørch, 2021)

According to Mørch (2021), to produce more durable iPhones, the manufacturers "*should make sure that the new software updates will not slow the old generations phones",* should focus on making the phones *"more water resistant"* and they should focus on "*making better batteries, to make sure that the battery is not worn- out as quickly, because right now is working 1-2 years then the battery is already worn-out and deteriorated*".

Lack of trust from de consumers when it comes to sensitive data

"*There are a lot of consumers that do not trust the fact that you can easily give away your computer if you have sensitive data on it that could be possible recovered. Devices that are placed on the market should allow for easy deletion of all data which will not be recoverable*" (Oldyrevas, 2021) Facilitating data transfer, deletion and encryption can help reuse (Oldyrevas, 2021)

Angouria-Tsorochidou (2021) explained that there are barriers even before an item is brought to a repair shop or a repair café. "*There are people that they do not feel secure in taken their phones and laptops to be fixed mostly in terms of personal data. That is the reason of having the case of storing in household of some items, quite often*" (Angouria-Tsorochidou, 2021).

6.2.3. Conclusion

This section will summarize the findings from literature review and interviews regarding the barriers that prevent the lifetime extension of smartphones and laptops. The information is presented in the table 7 below. The information is displayed in three columns smartphones and laptops, smartphones, laptops, according to the findings. Overall, it can be concluded that the barriers that prevent the lifetime extension of smartphones and laptops are related to: -legislative issues, software, firmware, and hardware issues, lack of repair information, deficient robustness, difficulty in accessing the spare parts, difficulty to repair, the cost of the repair, users concern regarding privacy data. For each of the barrier mentioned, more information are provided in the table below.

Barriers to extending the lifetime of smartphones and laptops

Findings from literature review				**Findings from interviews**		
	Smartphones + Laptops	**Smartphones**	**Laptops**	**Smartphones +Laptops**	**Smartphones**	**Laptops**
Legislative issues		-the two -year legal guarantee affects repair service and second hand refurbishment markets(Rizos et al. 2019) -lack of clarity regarding the refurbished products coming from outside EU and bearing a CE marking(Rizos et al. 2019)				
Software, hardware, and firmware issues		-the lack of regular software updates can shorten the lifetime of smartphones	-the software are evolving and in time can affect the performance of older laptops, until they will not be able to function	-firmware, software, updates have impact on the longevity (Oldyrevas, 2021)	-it is not easy to return to the previous version of the operating system (Oldyrevas, 2021)	-there is a need to update the software system when is becoming outdated

		(NGI Forward, 2021,Cordella et al. 2021).	properly (ECOS, 2020)		-iPhones are replaced after a short period of time because the motherboard is becoming too slow (Mørch,2021) -Apple stops updating the software, making impossible to install new applications (Mørch,2021) -impossibility of updating the software of phones (Angouria-Tsorochidou, 2021)	(Jørgensen ,2021) -over time, the software becomes outdated making the old laptops to be useless (Douglass, 2021)
Lack of repair information	the access to information regarding how to repair the devices is closely monitored by			-lack of consumer information regarding the repairability of devices (Oldyrevas, 2021)		

	the manufacturers and this creates difficulties for repairers and users to extend the lifetime of the devices (NGI Forward, 2021)					
Deficient robustness		-smartphones are replaced after a short period of time due to: failures, loss of performance, breakages(Cordella et al. 2021)	-the failures on laptops are related to hardware malfunction and accidental damages (ECOS, 2020)		-the iPhone battery must be replaced after a short period (1-2 years), the phones should be more water resistant (Mørch, 2021)	
Difficulty in accessing the spare parts				-it is one of the barriers to extending the lifetime of smartphones and laptops (Oldyrevas, 2021; Angouria-Tsorochidou, 2021)	Apple does not sell spare parts (Mørch ,2021).	-finding spare parts for keyboards is difficult because they are unique for every laptop model (Douglass, 2021)

Difficulty to repair		-the obstacle to repair the smartphones refer to: the lack of spare parts, high cost of repair, difficulty to disassemble and reassemble parts of the device(Cordella et al. 2021)	-the issues which can prevent the repair of laptops, refer to: integrated design, labor cost, unavailability, and difficulty in accessing the spare parts, high cost of spare parts (ECOS, 2020)	-serialization makes the repair process difficult (Oldyrevas, 2021) -phones and laptops have parts glued together and which create difficulty when repairing (Angouria-Tsorochidou, 2021)	-security software such as "software lock" can be an obstacle for the independent repair shops when repairing iPhones (Mørch,2021)	
The cost of the repair				given that the spare parts are bundled together it is expensive to repair the devices(Ooldyrevas, 2021)		-it is more costly to repair a laptop than to buy a new one (Angouria-Tsorochidou, 2021)
Users concern regarding privacy data			-because the laptops do not have an easy way to erase and reset the data, the users do not feel secure in providing them a second life (ECOS, 2020)	-people do not trust to give away their devices or to go to repair them due to personal, sensitive data on them (Oldyrevas, 2021; Angouria-Tsorochidou, 2021)		

Table 7 Summary of the findings from literature review and interviews of the barriers to extending the lifetime of smartphones and laptops

6.3 What are the main possible measures that EU could adopt to help extending the lifetime of smartphones and laptops?

After finding out what are the barriers that prevent the lifetime extension of the smartphones and laptops, this section aims to identify what could be the main possible measures to be adopted by the EU to address the problems. The data were collected using literature review and semi-structured interviews.

6.3.1 Findings from literature review

This section presents the findings from literature review concerning the possible measures that could be adopted by the EU to help extending the lifetime of smartphones and laptops.

Legislative measures

The minimum legal guarantee for new products is two years (as it was set by the Consumer Sales and Guarantees Directive 1999/44/EC) with the permission for Member States to increase this(Bachér et al., 2020). **Extending the minimum legal guarantee** could prolong the time over which the sellers could financially assist the repair of the products which might help extending the lifetime of products(Bachér et al., 2020)

Public repair information

The availability of repair manuals, diagnostic tools, schematics could be addressed through Sustainable Products Initiative (NGI Forward, 2021). This Initiative is reviewing the Ecodesign Directive framework (NGI Forward, 2021). Implementing the needed changes in this way could facilitate that the public repair information to be an Ecodesign principle for all relevant product sectors (NGI Forward, 2021). However, this approach could take several years, with changes starting in 2024 at the earliest (NGI Forward, 2021). For smartphones, in the shorter term, the publication of repair manuals, schematics, diagnostic tools should be included in the requirements for the vertical regulations which intends to cover the smartphones within the Ecodesign framework (NGI Forward, 2021)

Ecodesign requirements

The literature review showed that the software and firmware can represent a barrier to the lifetime extension of smartphones when they stop updating the device. According to NGI Forward (2021), there are two mechanisms which can help to implement a minimum software update duration in EU law. Both mechanisms involve the Ecodesign Directive. The first option proposed is to include a minimum software update duration in the (currently under development) vertical regulation for smartphones and tablets (NGI Forward, 2021). The second approach involves to include a minimum software update duration within the Ecodesign framework through Sustainable Products Initiative (NGI Forward, 2021)

For laptops, according to ECOS (2020) report, ecodesign requirements "*should be introduced for software and firmware updates to be made available for free for a minimum of ten years after placing the last unit of the model on the market*"

With respect to the deficient robustness, according to ECOS (2020) report, under the Ecodesign Directive should be introduced a minimum requirement specifying that manufacturers comply with available laptop durability standards which include beside standards related to shock resistance, also standards related to vibration, temperature stress, screen resilience, water spill, keyboard lifespan.

Regarding the difficulties to repair a laptop ECOS (2020) report suggest that the ecodesign regulation for computers should introduce requirements on replaceability of parts, requirements on availability of spare parts, requirements on repair information. Moreover, the ecodesign regulation for computers should introduce requirements on provision on data deletion tools in order to enable greater confidence in data sanitization, which could increase the user willingness to provide laptops a second life (e.g. by passing the laptops onto the second-hand market) (ECOS, 2020)

Repairability score on the EU energy label

According to ECOS (2020) report, a repair rating should be introduced on the EU energy label, displaying "*an aggregated score for the product in question*".

6.3.2 Findings from the interviews

The following section introduces the findings from the interviews, considering the possible measures that could be taken by the EU to help prolonging the lifetime of smartphones and laptops.

Information regarding the key instruments available at the EU level which can be used to extend the lifetime of smartphones and laptops were provided by Oldyrevas (2021) during the interview.

Oldyrevas (2021) mentioned that the European Commission has launched quite a few initiatives on product policy, listed in the Circular Economy Action Plan, and for smartphones and laptops the **key initiative** will be **Circular Electronic Initiative** planned for the end of the year. Under this initiative, the "*European Commission is planning to introduce ecodesign requirements (concerning repair, lifetime extension) for computers, smartphones and tablets and they are also considering printers" (Oldyrevas, 2021)*

He explained that the **Ecodesign** is a **tool** that can help extending the lifetime of the smartphones and laptops. Moreover, he pointed out that the Ecodesign preparatory study that has been done on smartphones and tablets is providing information regarding the extent to which the ecodesign measures can help address e.g., "*the ease of disassembly of these products, the provision of spare parts, the cost of spare parts, ease of data transfer and some software aspects*" (Oldyrevas, 2021)

Oldyrevas (2021) mentioned that the Ecodesign Regulation adopted in 2013 on computers addressed mostly energy efficiency and that the European Commission was supposed to review the Regulation in 2017, but the review has not yet been presented. The main issue is the fact that the current **minimum** ecodesign requirements related to the energy efficiency "*were based on metrics that did not consider computers performing any functions, so the energy efficiency formula only looked at sleep mode, idle state, off mood of the computers" (Oldyrevas, 2021).* As a result, the European Commission could not adopt an Energy label of computers, since the energy efficiency formula "*does not take into account how much energy a computer consume when is performing a computing function" (Oldyrevas, 2021).* No concrete proposal have been made even though the Ecodesign Regulation on computers was supposed to be reviewed since 2017 and is even much less advanced than the proposal on smartphones and tablets (Oldyrevas, 2021).

Oldyrevas (2021) pointed out that there are some ongoing studies in the Commission looking beyond ecodesign because there are some other aspects that could be addressed as well.

Another tool mentioned by Oldyrevas (2021) was the **Competition tools. "***There are a lot of concerns in how the repair market is foreclosed to the independent repairers through various commercial practices, so there should be much more regulatory intervention in addressing how easy or difficult it is for repairers to access spare parts, to access repair information" (Oldyrevas, 2021)*

Fiscal policy could also be helpful to extending the lifetime of the products, according to Oldyrevas (2021). "*It is very often cheaper to buy new than to repair and that for various reasons: the cost of spare parts, the fact that at the moment all the fiscal system is based on taxing labor rather than externalities, cheap virgin materials, some fiscal measures are needed - either as incentives or disincentives" (Oldyrevas, 2021)*

Oldyrevas (2021) mentioned that **Consumer information tools** are also needed to help the lifetime extension and explained that "*consumers need comparable information"* and they (ECOS) are "*advocating for a repair score to be introduced on the EU Energy label to guide consumers towards more repairable products in an easy-to-understand way*". He also suggested that the French repairability score should serve as a basis for the EU-level repair score.

Oldyrevas (2021) mentioned also that modularity could facilitate repair and refurbishment. Moreover, he highlighted the importance of repair. ***We believe that the repair market should be opened-up significantly as the overall goal should be to repair and not to buy new" (***Oldyrevas, 2021)

Regarding the measures that might be taken by the EU to extend the lifetime of laptops, Jørgensen (2021) mentioned that should be some demands on how much time you can update your laptop with a new software, to facilitate the installation of new software on old computers. Moreover, there should be some demands either on the manufacturers of the hardware or on the software developers so that "*this combination hardware-software to work together for some years*" (Jørgensen, 2021)

More than that, the EU could take some measures to recognize the used computers, to ensure that a warranty is received from the software developers when a new system has been installed on a used computer (Jørgensen, 2021). Jørgensen (2021) explained that the company Refurb it is

authorized by the Microsoft to install the software on used computers ensuring the same lifetime of the software.

With respect to the measures that might be taken by the EU to help extending the lifetime of laptops Douglass (2021) mentioned that they are supporting the European "Right to repair" movement and that this initiative could address the availability of spare parts.

Another issue that might be addressed as well, is the fact that some computers have security mechanisms (passwords impossible to break) which can prevent the refurbishment companies from doing their job. In this regard, he suggested that there should be some protocols allowing manufacturers to trust the refurbishment companies, enabling them to refurbish the old computers (Douglass, 2021)

During the interview with Angouria-Tsorochidou (2021), the measures that can be taken by the EU to help extending the lifetime of smartphones and laptops were also discussed. She pointed out that legislation on how long products should last is needed. Moreover, "*ecodesign requirements for the product that are going to the market, in order to be repairable and to ensure spare parts"* are also needed (Angouria-Tsorochidou ,2021)

6.3.3. Conclusion

This section summarizes the findings from literature review and interviews regarding the measures that might be taken by the EU to help extending the lifetime of smartphones and laptops. The information is presented in the table 8 below.

Overall, it can be concluded that the main possible measures that might be taken by the EU to help extending the lifetime of smartphones and laptops could be related to: legislative measures, public repair information, ecodesign requirements, competition tools, fiscal policy, consumer information tools, demands on the manufacturers, right to repair, measures concerning the warranty. For each of the possible measure mentioned, more information are provided in the table below.

Measures that might be taken by the EU to help extending the lifetime of smartphones and laptops

Findings from literature review				**Findings from interviews**		
	Smartphones +Laptops	**Smartphones**	**Laptops**	**Smartphones +Laptops**	**Smartphones**	**Laptops**
Legislative measures	-extending the minimum legal guarantee could help extending the lifetime of products (Bachér et al., 2020)					
Public repair information	-the Sustainable Products Initiative could address the availability of repair manuals, schematics, and diagnostic tools (NGI Forward, 2021)	-the publication of repair manual, schematics, diagnostic tools could be included in the requirements for the upcoming vertical regulations on smartphones (NGI Forward, 2021)				
Ecodesign requirements		-to include a minimum software update duration in the vertical regulation for smartphones and	-ecodesign requirements should be introduced for software and firmware updates,	-Ecodesign is a **tool** which can be useful in extending the lifetime of smartphones and laptops (Oldyrevas, 2021)		

		tablets (NGI Forward, 2021)	for laptops (ECOS, 2020) -the ecodesign regulation for computers should introduce requirements to address the difficulties to repair such as spare parts availability, repair information (ECOS, 2020) -the same regulation should introduce requirements regarding data deletion tools (ECOS, 2020)	- the "Circular Electronic Initiative" under which the European Commission is planning to introduce ecodesign requirements for smartphones and laptops (Oldyrevas, 2021), is a **key initiative** which might help the lifetime extension -ecodesign requirements for the products to be repairable and provide spare parts (Angouria-Tsorochidou, 2021)		
Competition tools				-regulatory intervention to help independent repairers to access spare parts, access repair information (Oldyrevas, 2021)		

Fiscal policy				fiscal measures (incentives or disincentives) might help in addressing the repairability of the products because often is cheaper to buy new than to repair (Oldyrevas, 2021)		
Consumer information tools	-a repair rating should be introduced on the EU energy label (ECOS, 2020)			-consumers need comparable information on the products. A repair score should be introduced on the EU Energy label to guide consumers in choosing repairable products and the French repairability score should serve as a basis for the EU score (Oldyrevas, 2021)		
Demands on the manufacturers				modularity could help repair and refurbishment (Oldyrevas, 2021)		-demands regarding how much time the laptops can be updated with new software. This will help installation of new software on old

						laptops (Jørgensen, 2021) -protocols enabling the manufacturers to trust the refurbishment companies and permit them to refurbish old computers, because sometimes laptops have passwords impossible to break, preventing the refurbishment companies to do their job (Douglass, 2021)
Right to repair						-the Right to repair could address the availability of the spare parts (Douglass, 2021)
Measures concerning the warranty				-legislation on how long product should last (Angouria-Tsorochidou)		-ensuring that a warranty is received from the software developers when a new software is installed on a used computer (Jørgensen, 2021)

Table 8 Summary of the findings from literature review and interviews of the measures that might be taken by the EU to help extending the lifetime of smartphones and laptops

7. Discussion

This section is discussing the findings related to the barriers to extending the lifetime of smartphones and laptops and related to the measures that might be taken by the EU to help addressing this issue, presents the critical reflections on conducting this research, presents the reliability and validity of the research and suggestions for further research.

7.1. Discussion of the findings

The table 7 of this research summarized the findings from literature review and interviews of the barriers to extending the lifetime of smartphones and laptops. The most prevalent issues related to the lifetime extension of smartphones and laptops, which were identified by the interviewees and were found also in the literature review are related with the software, firmware, hardware issues. One of the most important issue highlighted during the interviews and identified in the literature, was the lack of software/firmware updates for older devices. It is important mentioning the fact that this barrier was identified by all the interviewees. This issue leads to shortening the lifetime of smartphones and laptops. Difficulty to repair is another important barrier that prevent the lifetime extension of the products investigated. This issue was pointed out by three of the interviewees and was also revealed in the literature. Deficient robustness and difficulty in accessing the spare parts were also identified as important barriers to overcome.

The table 8 of the research summarized the findings from literature review and interviews concerning the measures that might be taken by the EU to help extending the lifetime of smartphones and laptops. According to the findings, the introduction of ecodesign requirements (concerning eg. software updates, spare parts availability, repair information, requirements regarding data deletion) are the main measures that should be taken by the EU to help extending the lifetime of smartphones and laptops. The ecodesign requirements were suggested by two of the interviewees and found in the literature. Also, the demands on the manufacturers and the right to repair measures could also be included in the ecodesign requirements.

7.2. Critical reflections on the research

A limitation of this study could be represented by the fact that to gather empirical data regarding the barriers to extending the lifetime of smartphones and laptops, the interviews were conducted mostly with interviewees from Denmark. Could be that other repair companies or refurbished companies from other European countries encounter different/more barriers when repairing smartphones and laptops.

The intention was to conduct more interviews, with repair companies of smartphones and laptops but it was not possible due to the lack of willingness of the persons approached. It would have been beneficial also to conduct interviews with representatives from manufacturing companies, but no available companies to provide interviews were found.

As presented in the literature review, to collect data regarding the barriers to extending the lifetime of smartphones and laptops and regarding the measures that might be taken at the EU level, only six documents (articles and reports) were used. If more documents have been used it would have resulted in more information.

Sometimes, it was not easy to follow some of the interviews conducted due to the technical terms used, related to smartphones and laptops components, software, programming. Since most of the interviews were conducted by phone, sometimes the sound was not very clear.

7.3. Reliability and validity of the research

This research rely on the literature review and on the semi-structured interviews. Section 3 of the research (Consumer electronic products) presents the framework of the study and the context of this research. The literature review was performed using literature produced by reliable publications and websites. Moreover, the investigation of the barriers to extending the lifetime of smartphones and laptops and the measures that might be taken by the EU to address this issue was done by reviewing reliable articles and publications. Therefore, the literature review is considered valid and reliable. The semi-structured interviews conducted are also reliable and valid as they

were performed with different experts in their specific field. It can be concluded that the findings of this research can be perceived as valid and reliable. However, if more interviews have been conducted and more articles and publications have been investigated regarding the barriers to extending the lifetime of smartphones and laptops and concerning the measures that might be taken by the EU, it is possible that this could have influenced the findings of this research. It is possible that more barriers to extending the lifetime of the products investigated and more possible measures to be adopted by the EU, to be identified.

7.4. Further research

This small research could serve as a starting point for a more in-depth research involving interviews with representatives from all key actors that might help to extending the lifetime of smartphones and laptops. Moreover, further research should focus on conducting a more thoroughly literature review of the barriers to extending the lifetime of smartphones and laptops and on the measures that might be taken by the EU to address the situation. More than that, further research could also investigate the possible measures that the EU could adopt to facilitate the lifetime extension of other product groups.

8. Conclusion

This research has investigated *How can European Union (EU) break down the barriers to extending the lifetime of smartphones and laptops?*

To answer this question, the instruments available at the EU level which might help the lifetime extension were addressed and investigated. Moreover, three sub-questions have been formulated to help answer the main research question. The first sub-question investigated the environmental impacts caused by the smartphones and laptops. The purpose was to highlight the fact that these products have high environmental impacts and that extending their lifetime it is more environmentally friendly than producing new devices. The conclusion showed that there could be considerable environmental savings if the lifetime of smartphones and laptops is extended.

The second sub-question has investigated what the barriers are to extending the lifetime of smartphones and laptops. To achieve this, literature review and semi-structured interviews were performed. The conclusion of this sub-question, (as presented in the 7.1. Discussion of the findings) revealed that the most prevalent issue is related wit the software/firmware updates. Other important barriers are related with difficulty to repair, deficient robustness, and difficulty in accessing the spare parts.

The third sub-question has investigated what measures might be taken by the EU to help extending the lifetime of smartphones and laptops. This sub-question is also providing the answer for the research question.

The findings show that ecodesign requirements are the most important measures that should be introduced to address the most important issues related to the lifetime extension of smartphones and laptops. Apart from that, the introduction of a repair score on the EU energy label, fiscal measures, competition tools and measures concerning the warranty are also important measures that might help to extend the lifetime of smartphones and laptops.

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10. Appendix

For the interviews conducted were prepared guidelines, which are portrayed below:

Interview guideline: Philip Douglass

Can we record the interview for the educational purpose?
Can you introduce yourself? What is your position at Fair Denmark?
I saw on the website that FAIR's key activity is refurbishment of ICT products. You happen to face certain obstacles when refurbishing a laptop? What would those be?
Why do laptops break down easily in your experience?
What are the most common causes that lead to a laptop break down?
What manufacturers should do to produce a more durable laptop?
What measures should be taken at the European level to help extending the lifetime of laptops?

Interview guideline: Martin Mørch

Can we record the interview for the educational purpose?
Can you introduce yourself? What is your position at iPhone Repair?
Why do iPhones break down easily in your experience?
You happen to face certain obstacles when repairing an iPhone? What would those be?
What are the most common causes that lead to an iPhone to break down?
What the manufacturers should do to produce a more durable iPhone?

Interview guideline: Ernestas Oldyrevas

Can we record the interview for the educational purpose?
Can you introduce yourself? What is your position at ECOS?
In your opinion, there are barriers to extending the lifetime of smartphones? What about the laptops?
Which actors do you see as important to overcome the barriers? What could these do?

What are in your opinion, the main barriers that the smartphones and laptops are facing, regarding the lifetime extension?
What are your suggestion on how to overcome the barriers to extending the lifetime of smartphones and laptops?
What are the key instruments available at the EU level which can be used to help the lifetime extension of smartphones and laptops? What measures could be adopted by the EU, under these key instruments, to promote the lifetime extension of smartphones and laptops?

Interview guideline: Elisavet Angouria-Tsorochidou

Can we record the interview for the educational purpose?
Can you introduce yourself? What is your position at Repair Café Denmark?
How are Repair Cafes different from repair shops?
At the Repair Café do you happen to repair ICT products such as smartphones and laptops?
In your experience, what are the barriers to extending the lifetime of products such as laptops, smartphones?
How are Repair Cafes contributing to extending the lifetime of the products?
You happen to face certain obstacles when repairing a smartphone/laptop? What would those be?
What measures could be taken at the European level to help extending the lifetime of smartphones and laptops?
What are in your opinion the key actors to overcome the barriers to extending the lifetime of smartphones and laptops?

Interview guideline: Michael Søgaard Jørgensen

Can we record the interview for the educational purpose?
Can you introduce yourself? What is your position at Aalborg University?
In your opinion, there are barriers to extending the lifetime of smartphones? What about the laptops?

What are in your opinion, the main barriers that the smartphones and laptops are facing, regarding the lifetime extension?

Which actors do you see as important to overcome the barriers? What could these do?

What are your suggestion on how to overcome the barriers to extending the lifetime of smartphones and laptops?

What are the key instruments available at the EU level which can be used to help the lifetime extension of smartphones and laptops? What measures could be adopted by the EU, under these key instruments, to promote the lifetime extension of smartphones and laptops?