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Planned obsolescence in the age of sustainability

Alternatives to disposable technology

Bachelor's Thesis
Jenni Tuominen
Aalto University School of Business
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Aalto University
School of Business

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

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Author Jenni Tuominen

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Abstract

While concern for environmental issues is growing with the increasing awareness of climate change, consumption levels continue to rise. Planned obsolescence is a business model that durable goods producers depend on for continuous profits, as it encourages repeated consumption of durable products through shorter product lifecycles.

Obsolescence is especially rampant in the technology sector, where competition is intense and innovation is fast-paced. While excessive consumption of gadgets generates considerable profits, it comes with a price for the environment. Electrical and electronic products cause greenhouse gas emissions, deplete resources, and demand energy. When the products become e-waste at the end of life, they can cause harm on both people and the environment.

This thesis explores the how and why of planned obsolescence in the contemporary technology sector. Research is put into context through recent examples of planned obsolescence. Possible alternatives for dependence on obsolescence are explored through both literature and concrete business examples. Sustainability reports of big technology companies are also evaluated to see how business management is addressing problems caused by obsolescence.

Keywords planned obsolescence, circular economy, sustainability, durable goods

Table of Contents

List of Tables

1 Introduction

Climate change is the most pressing issue of our time, as evidenced by IPCC's landmark Sixth Assessment report, which combines together the latest advancements in climate research. The research shows that human-induced global warming is already affecting the climate in various ways, from droughts to floods and from wildfires to cyclones. Many changes, such as those of rising global sea level and ocean temperature, are already irreversible for millennia. Meeting the Paris agreement target of limiting global warming to below 2.0°C requires deep reductions in all greenhouse gas emissions within the next few decades. (IPCC *et al.*, 2021)

As the dangers of climate change have become largely acknowledged, more and more public policies attempt to address the impacts that industry has on the environment. Awareness of climate change has also made many consumers more conscientious in their purchasing choices. The combination of public policies and consumer concern means that acting more sustainably is increasingly in the interest of companies. Sustainable development, as outlined by The Brundtland Commission in 1987, is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Durable goods producers face a notable environmental and economical dilemma: how to reconcile product durability with continuous profits. Long-lasting and reliable products lead to longer repeat purchase cycles, and thus to slower sales growth. This challenge is even greater in industries where fast product development and innovation are essential for competition, such as the technology industry. Planned obsolescence has historically been the answer to this "durables problem", as it enables a steady flow of revenue to the company and ensures competitivity in the market. (Slade, 2006; Guiltinan, 2009)

However, constantly pushing out new products results in both increased production emissions and specific waste problems such as health implications and environmental pollution (Bakhiyi *et al.*, 2018). Because of these impacts, public policies are also beginning to take note of the phenomenon of planned obsolescence, especially in Europe (Maitre-Ekern and Dalhammar, 2016). In view of the growing number of policies around sustainability and a circular economy, companies should consider new business models to grow out of their dependence on product obsolescence.

Planned obsolescence is defined as artificially limiting the durability of a manufactured good to increase its consumption (Slade, 2006). In other words, its core objective is to stimulate replacement purchases (Guiltinan, 2009). The term dates back at least to 1932, when real estate broker Bernard London proposed that the government should increase Depression-era production by restricting the lifetime of products in his pamphlet "Ending the Depression through Planned Obsolescence" (Slade, 2006).

The concept of planned obsolescence was popularized by Vance Packard in the late 1950s. In his book The Waste Makers (1960), he divided obsolescence into obsolescence of function, quality, and desirability. Obsolescence of function refers to a product becoming outmoded because of technological advancements. Obsolescence of quality means that a product is deliberately made to break down or wear out at a given time. Obsolescence of desirability, or psychological obsolescence, means that a product becomes undesirable in the mind of the consumer. (Packard, 1960)

Cooper (2004) extends on Granberg's (1997) distinction of two main types of obsolescence, absolute and relative. Absolute obsolescence refers to the intrinsic durability and repairability of a product, while relative obsolescence is caused by the consumer comparing old and new products. Granberg divides relative obsolescence further into functional and psychological obsolescence. Functional obsolescence is caused by economic depreciation, new technologies, or changing personal needs due to circumstances, and psychological obsolescence refers to a subjective change in the mind of the product's user, such as concerning fashion. Cooper, on the other hand, divides relative obsolescence into technological, psychological, and economic obsolescence, the latter representing financial factors such as an old product becoming more expensive to upkeep than a new one. (Cooper, 2004)

Guiltinan (2009) also distinguishes two main types of obsolescence, physical and technological. Physical obsolescence includes limited functional life design ("death dating"), limited repairability, and design aesthetics that lead to reduced satisfaction. Technological obsolescence refers to design for fashion and design for functional enhancement through adding or upgrading product features. (Guiltinan, 2009)

Many similarities can be seen between these different terminologies. In this thesis, I will be using the following terms: physical obsolescence, technological obsolescence, and psychological obsolescence. I have chosen these three terms as I see that they best describe the planned obsolescence present in consumer electronics today.

Physical obsolescence refers to a product becoming obsolete because of its physical properties, such as its repairability and durability. Technological obsolescence happens when technological improvements make old models obsolete, such as smartphones making regular phones, or even other smartphones, obsolete. Psychological obsolescence means that a product becomes undesirable in the mind of the consumer, such as when a new product simply looks better than the old one.

While some amount of research has been made on planned obsolescence in general (193 hits for the search "planned obsolescence" on Scopus), research on how it is present in technology companies, and more specifically in the electronics sector, today has not been conducted. This thesis aims to answer that gap by looking at both the existing scientific literature and the latest sustainability reports and developments of contemporary technology companies. Possible solutions for technology companies are also presented.

1.1 Research objectives

The purpose of this thesis is to explore the three forms of planned obsolescence in contemporary technology companies manufacturing durable goods, and to critically evaluate the proposed alternatives for the practice. The thesis should deliver an overview of planned obsolescence in the technology industry.

First, I will examine how planned obsolescence has become a widely accepted standard for durable goods. Why is planned obsolescence still so prevalent despite the ever-growing concern for the environment and recent trends of sustainability?

Second, I will consider what kind of alternatives exist in the market for durable goods. What are some examples of alternative solutions which have been implemented, and what are their benefits and disadvantages? How are these solutions utilized by big technology companies?

1.2 Scope of research

This thesis focuses on the products of technology companies operating in the field of consumer electronics ("black goods"), such as mobile phones, computers, or TVs. Electrical household appliances ("white goods"), e.g. dishwashers, are also considered to an extent as all electronics face obsolescence in a similar, although not identical, way.

The research does not consider technology products marketed to and used by businesses or product lifecycles in business use. The focus is exclusively on B2C relations.

Planned obsolescence occurs in many big industries, perhaps most prevalently in fashion, but these industries are out of scope for this thesis. A minor exception to this is in chapter 3.1 when presenting an overview of the history of the practice.

In chapter 4, the alternatives proposed for planned obsolescence only include solutions that are relevant to consumer-oriented electronics. The solutions are targeted to business management. Public policy options, such as tax reforms, are not the focus of this thesis. Public policies are only considered to the extent where they can influence the future of the technology industry and the decisions made by technology companies, as in chapter 4.1.

1.3 Structure of the thesis

The rest of the thesis is structured as follows. Chapter 2 presents the methodological approach for this literature review, including the key phrases and criteria for searching the literature. Chapters 3 and 4 present the main body of the literature review.

Chapter 3, "Planned obsolescence as a phenomenon", first introduces the history of planned obsolescence. Then I look at how obsolescence is present in the technology sector today through both literature and news articles. Finally, I present an overview of what environmental problems the phenomenon causes.

In chapter 4, I look at the different solutions that have been proposed for planned obsolescence. I start the chapter with an introduction to the policies which affect company decisions related to the matter, and then I move on to examine the three main solutions proposed by literature: recycling, longer lasting products, and product-service systems. I go over their problems and advantages, as well as some real-life examples. In the last subchapter I look at how big technology companies are addressing the issue, as presented in their sustainability reports.

Finally, chapter 5 concludes the review. The chapter consists of discussions and implications for practice, as well as the limitations of the study and suggestions for future research.

2 Methodology

I have loosely based my methodology for this literature review on techniques of Systematic Literature Reviews as described in the books Literature Reviews by Cardoso Ermel et al. (2021, chapter 6) and Systematic Approaches to a Successful Literature Review by Booth et al. (2012, chapters 5-8). I mainly focused on peer-reviewed research articles in English. In addition, I used grey literature in the form of reports, statistics, and news articles.

The research articles included in this review have been found by directly searching on the database Scopus. Data was collected from October to December 2021 using the following search terms: “planned obsolescence”, “planned obsolescence” AND technology, “circular economy”, “throwaway society”, “product service system”. I have based the a priori inclusion criteria of the articles on the publishing date and number of citations. The articles have been found by filtering for the highest number of citations and I have only considered articles published in the last 20 years.

Based on the most relevant article titles, I have reviewed the abstract and conclusions of interesting papers to determine if they fit the topic. The article must be relevant to the topic of planned obsolescence in the B2C technology industry. After reading the full-text, I have included the article based on whether it provided new and useful insights for this research. I have also searched for articles by snowballing the most significant articles, i.e. by searching for literature from their reference lists. In cases where now obsolete statistics have been quoted, I have searched for more recent sources (e.g. the amount of electrical waste generated has varied along the years).

To get a picture of how companies are addressing the issue of planned obsolescence today, I have looked into the sustainability reports of Apple, Intel, Microsoft, Samsung, Huawei, and Sony in chapter 4.5. These companies were based on their status as the biggest contemporary actors in technology manufacturing durable goods. The reports were acquired from the companies’ websites in the beginning of December, and all of the reports state that they have been reviewed by an independent third party.

Other reports that I have included are IPCC’s Sixth Assessment report (2021), UN’s Global E-waste Monitor (2020), Eurostat’s Waste statistics (2021), and Survey on the Internet Usage by the Ministry of Science and ICT and Korea Internet & Security Agency (2017). All of these publishers are generally deemed credible, and the studies have also been referenced in other research papers. The rest of the statistics used in this thesis have been found on data platform Statista, and confirmed to be valid by examining the direct source at the reference link provided by Statista.

The news articles about recent cases and developments of planned obsolescence in chapter 3.2 have been found by first searching on Google using the search term “planned obsolescence [company]”, company representing the six companies reviewed in 4.5. By doing this, I have identified the most relevant cases. After choosing to include a news topic, I have attempted to find the most recent information available for the case, and checked what other news outlets have reported on the event to minimize chances of misinformation.

The grey literature used is justified as the contextual information is important to the studied subject, as expressed in “Table 6.5 Questions to decide whether to include grey literature” by Cardoso Ermel et al. (2021), adapted from Garousi et al. (2018).

3 Planned obsolescence as a phenomenon

In this section I will first present the historical origins of planned obsolescence. Then I will examine how it materializes in the technology industry today, and finally what environmental problems the obsolescence of electronics causes.

3.1 The history of planned obsolescence

The history of obsolescence is tied closely with that of consumerism. In the book Made to Break, Slade (2006) presents the history of planned obsolescence as "an American invention". Slade recounts that as a result of labour shifting from manpower to machines, overproduction was a problem already in the 1870s. The solution was to sell more products, which resulted in the rise of advertising. A specific problem for sales was how to ensure repetitive consumption, and one of the strategies for solving it became planned obsolescence, in three distinct stages. (Slade, 2006)

Slade considers technological obsolescence to be the first stage of planned obsolescence, sprouting from the competition between General Motors and Ford. GM competed with the more successful Ford by investing in continuous development, constantly pushing out improved versions of their cars. In doing so, GM began a trend of always looking for "the next best thing" which would make previous products obsolete. (Slade, 2006)

In 1923, GM changed its strategy to incorporate not only technological advancement, but also changes in fashion, i.e., the appearance of the car. Other manufacturers followed in GM's footsteps, and so began the second stage of obsolescence: psychological obsolescence. This was well-suited for the affluent 1920s, where disposability had become the norm and thrift and durability were generally rejected. (Slade, 2006)

When the Great Depression hit in the 1930s, design competition was not enough, and the practice of "adulteration" or making products cheaply by reducing quality became common. As a result, product lifespans shortened and the third stage of obsolescence, physical obsolescence, began. A famous example of this is General Electric experimenting with shortening the lifetime of their lightbulbs as a way of stimulating repetitive demand. This practice of shortening product lifespans is called "death-dating", and it became common by the 1950s. Around this time, the concept of "planned obsolescence" became hotly debated in the public as a response to a series of books focused on consumerism released by Vance Packard. (Slade, 2006)

Packard identified the post-war era as "the Throwaway Age", where Americans had been conditioned to become "waste makers" to sustain economic growth and keep up personal appearances. Things that used to last for life, such as furniture and appliances, were now regularly replaced, and single-use packaging became the norm. For manufacturers, the benefit was endless demand, while for consumers it was convenience. (Packard, 1960) Slade (2006) identifies that our "disposable culture" or "the throwaway ethic" was born already around the middle of the 19th century with the wide availability of cheap materials such as paper and steel. Similarly, Cooper (2005) maintains that we are currently living in a "throwaway society", seeing as waste has been increasing at the same rate as economic growth.

The throwaway ethic directly enables planned obsolescence. In a study by Cox et al. (2013), participants rarely considered the environmental impacts of short product lifecycles, and few felt guilty about replacing their still functioning products with new ones. Another study by McCollough (2007) found that as incomes rise, consumers shift towards replacing products as opposed to repairing and maintaining them because of the opportunity cost of time. He argues that goods are so inexpensive relative to the wage rate that disposing of them is profitable.

The concept of throwaway society has been critiqued by Gregson, Metcalfe and Crewe (2007), who found that objects are often donated to charities or family members, and discarding products often produces anxiety and guilt. The paper argues that the throwaway ethic does not exist, and other social factors are at play. However, the results of the study seem to support the idea of a throwaway culture, as participants did throw many possessions into the trash instead of recycling them or giving them away. It can also be noted that the participants rarely bought secondhand products themselves, and products were often discarded because of status concerns.

3.2 Contemporary obsolescence and technology

The shift to an information society started a new phase of obsolescence. Already in the 1990s, PCs were being traded up regularly for upgraded versions. (Slade, 2006) As innovation has become vital for companies to remain competitive, product development must constantly push out new and improved products. This frequent introduction of new models incentivises consumers to replace their old devices, even if they still work. The amount of still functioning products being discarded is evidence of the shift from physical obsolescence to technological and psychological obsolescence. (Guiltinan, 2009)

The prevalence of physical obsolescence today is unclear, as reliable data about the historical lifespans of products is lacking (Cooper, 2005). Already in the 1950s, there was general dissatisfaction with product lifetimes, as many Americans felt that products didn't last as long as they used to (Packard, 1960). A study by Cooper and Mayers in the UK in 2000 also found that many people believe product lifespans have become shorter (Cooper, 2004), and a newer UK study by Cox et al. (2013) came to the same conclusion with their discussion groups. Similar results have also been attained in Brazil (Echegaray, 2016). While the evidence is mostly anecdotal and relies on memory, it seems that shorter lifespans could be a continuing historical trend.

Even so, people do not necessarily want their products to last longer. The study by Cox et al. (2013) discovered that consumers expect to upgrade their products within a certain period of time regardless of whether they break down or not. According to the study, people feel vast social pressure to keep up with the latest products and staying up to date is associated with personal success. Cooper's (2004) study also found that people do not want their products to be out of date. Echegaray's study in Brazil (2016) similarly concluded that psychological reasons greatly contribute to consumers discarding products, with many participants reporting that they replace products for modernity and higher social value. Considering these studies and the speed of new products hitting the market, the influence of technological and psychological obsolescence is clear.

But where is the line between technological and psychological obsolescence? Are consumers buying the newest gadgets because of technological progress or psychological reasons? Packard (1960) proposed that obsolescence is more of desirability (psychological) than of function (technological) if the technical improvement is so minor that it might not be considered a genuine improvement at all. As generating substantial technological innovations at a fast pace is impossible, a company might release a new product with minor changes and market it as a great improvement. Therefore, it could be suggested that the significance of the made improvement should be the deciding factor in whether the obsolescence of a product is considered psychological or technological, although it can be challenging to determine what improvement is significant enough.

Microchips are one example of pure technological obsolescence. When Moore's Law (1965) observed that the number of transistors in an integrated circuit roughly doubles every two years, it simultaneously forecasted the circuits' consequential technological obsolescence. Each microchip and the devices dependent on it are practically death-dated from birth. The problem is not constrained to just microchips either, as exponential growth is a law in computing in general, and technology has progressed at a faster pace than any other industry. (Slade, 2006)

The growing number of products is not the only side effect of innovation. The minimization of chips and other electrical parts has made resource recovery by recycling increasingly difficult, as parts require more complex mixtures of components (Bartl, 2014). Furthermore, e-products often employ design choices that discourage repair, such as glued components (Bakhiyi *et al.*, 2018). Design choices of electronic products therefore seem to favour obsolescence and exacerbate waste issues.

Because of their dubious design choices and constant releases of new products, technology companies are occasionally publicly accused of planned obsolescence both in the media and in court. However, these claims are often dismissed by appealing to innovation or necessary design choices, and it is challenging to prove deliberate intent of planned obsolescence. For example, the iPhone's battery has been claimed to be sealed in for aesthetical reasons, to make the product lighter, and to prevent dirt from getting inside – not to hinder battery replacement. (Maitre-Ekern and Dalhammar, 2016)

Apple has exhibited some of the most notorious examples of modern planned obsolescence. In 2017, Apple was proven to be slowing down older devices with an iOS update, which pressured many users to buy a newer model of their phone. Apple claimed that this was necessary to prevent sudden shutdowns of the phones, but they settled a US class action lawsuit for up to $500 million (USD) and a state investigation for $113 million, on top of which they were fined with $25 million in France. (Romm, 2020) This was not the first time Apple was accused of planned obsolescence for slowing down older phones, as they were already making the news for doing it in 2013 (Simpson, 2013).

Apple is also known for the poor repairability of their products. In 2016 an iOS update rendered phones which had been serviced by independent repairers unusable, forcing some users to buy new phones. Apple later offered reimbursements to the users and a patch for the problem. However, the affected phones' touch ID buttons, serviced by third-party repairers, were left disabled "for security reasons". (Chokkattu, 2016) "Security reasons" have also been cited by Microsoft for only supporting their newest OS, Windows 11, on devices with TPM 2.0 support – barring PCs bought as recently as 2019 from the update. This has been considered an arbitrary requirement by many. (Warren, 2021)

In addition to security reasons and necessary design choices, innovation is also used to excuse different forms of unethical business practice. Recently in an effort to reduce e-waste, the European Commission has proposed that USB-C should become the universal standard for charging cables. Apple, whose products use their proprietary Lighting cable, protested that the proposal would stifle innovation. (Weaver, 2021)

Considering all the factors contributing to obsolescence in technological products, it is no wonder that the replacement cycles for consumer electronics are very short. According to one survey, the average global smartphone replacement cycle in 2016 was 2 years and 4 months (Morgan Stanley, 2017). Another survey found that in 2020 the average replacement cycles for PCs and tablets in the United States were estimated to be 4.75 years and 4.2 years respectively (Statista, 2021). The estimates are in line with a study by Cox et al. (2013) in which consumers expected to replace most of their electronics within 5 years of purchase, and mobile phones specifically within 2 years. A previous study by Cooper (2004) also found that consumers don't expect long durability when it comes to small appliances, such as mobile phones.

In a 2017 national survey, the average replacement cycle for smartphones in South Korea was 2 years and 8 months. The main reason for replacement was "contract expiration" (33.9%), followed by "machinery malfunction" (32.3%). Psychological and technological obsolescence factors, i.e., "outdated functions" (16.1%), "interest in new phone" (8.1%) and "tired of existing phone" (5.5%) amounted to 29.7% of the answers. (Ministry of Science and ICT and Korea Internet & Security Agency, 2017) It would thus seem that durability and psychological factors contribute to replacements nearly at the same rate. However, "contract expiration" can disguise psychological obsolescence, as limited-term contracts might be made because of a desire to upgrade one's phone every few years.

From this overview, it is clear that technology companies practice and benefit from multiple types of planned obsolescence. Much of modern obsolescence happens in the mind of the consumer, and the line between psychological and technological factors has blurred. It is also difficult to determine how much of the responsibility for short product lifespans falls on the companies churning out new products, and how much on the consumers enthusiastically upgrading their gadgets.

3.3 The environmental cost: from greenhouse gases to landfills

Consumer electronics cause pollution and consume resources both in the manufacturing phase and at the end of life when they become e-waste. Moreover, their usage can also require significant amounts of energy.

When considering length of lifetime, production energy, and use phase energy, the production phase is the biggest cause of emissions for many electronic devices. For smartphones, production energy is 85-95% of their carbon footprint, mostly because of short product lifetime. (Belkhir and Elmeligi, 2018) In 2020, product manufacturing made up 71% of Apple's carbon footprint (Apple Inc., 2021) and 80-95% of Huawei devices' carbon footprint (Huawei Technologies Co., 2021). It can be concluded that producing electronics is environmentally expensive, and short lifetimes fuelled by obsolescence exacerbate the problem.

Most research on the environmental impacts of electronics is focused on e-waste. The UN's Global E-waste Monitor (Forti *et al.*, 2020) uses the Step Initiative's definition for e-waste: "EEE [electrical and electronic equipment] becomes e-waste once it has been discarded by its owner as waste without the intent of reuse". Further, EEE is defined as "products with circuity or electrical components with a power or battery supply".

In 2019, 53.6 million metric tonnes (Mt) of e-waste was generated globally, which is an average of 7.3 kg per capita. By 2030, the amount of annual e-waste is estimated to grow to 74.7 Mt. The growth of e-waste is a result of growing EEE consumption, short life cycles, and poor repairability. (Forti *et al.*, 2020) Planned obsolescence, which results in short life cycles and a lack of incentives for product repair, greatly drives the generation of e-waste (Bakhiyi *et al.*, 2018).

A staggering 82.6% (44.3 Mt) of all e-waste was dumped, traded, or recycled in a non-environmentally friendly way in 2019. Among other chemicals, these unaccounted flows of waste contained approximately 50 tons of mercury, which is damaging to humans and animals. (Forti *et al.*, 2020) In other words, most of the e-waste generated each year ends up polluting the environment.

E-waste can contain both valuable recyclable materials such as gold and copper and hazardous substances such as lead and cadmium. Firstly, the materials which are not recycled are lost and cannot reduce production emissions by substituting primary raw materials. Secondly, uncontrolled hazardous materials lead to several environmental and health damages. This is especially bad for developing countries, where the waste is often illegally exported to. (Bakhiyi *et al.*, 2018)

Illegal exports usually end up in places with informal e-recycling activities, where e-waste contaminants affect both the recycling workers and the general population. Informal recyclers often do not have the means to protect themselves from the carcinogenic and toxic substances contained by e-waste. Additionally, contaminants such as heavy metals, flame retardants and PCBs pollute the local air, soil, and water. This environmental damage will take a long time to erase. (Bakhiyi *et al.*, 2018)

A review by Belkhir and Elmeligi (2018) found that the contribution of ICT to worldwide greenhouse gas emissions would roughly double from 1-1.7% in 2007 to 3-3.6% in 2020, and by 2040 it could be 14%. As both emissions and e-waste amounts are projected to increase, the electronics industry bears much of the responsibility in environmental issues. Planned obsolescence directly influences the amount of environmental damage and should thus be considered a major sustainability issue.

4 Solutions to obsolescence

Solving the problem of climate change, and that of planned obsolescence, is dependent on both legal action and private investment. In this chapter I will first provide an overview of public policies aiming to change the industry standards, and then I will look at the possible solutions for the private sector. Finally, I will examine how obsolescence is considered in company sustainability reports.

4.1 Circular economy and policy as the basis for change

Public policies are indispensable for solving the environmental crisis. Many of the solutions presented later in this chapter won't be worthwhile for companies without public regulation and legislation, as generating endless streams of waste and emissions is profitable as is. Many of the mentioned policies are based on extended producer responsibility (EPR), which places the responsibility of the whole lifecycle of a product on its manufacturer. EPR is meant to incentivise manufacturers to also consider the product's end of life in its development (Cooper, 2005). Thus, companies may be pushed to adopt practices such as better repairability and recyclability.

More and more countries are adopting regulation for the handling of e-waste. As of October 2019, 78 of the 193 countries of the world had implemented a national e-waste policy, legislation, or regulation. This covered 71% of total world population. However, all of the policies are not legally binding, and most countries of the world have no policy at all. Most e-waste policies also fail to address waste prevention by promoting reuse and repair, concentrating instead on recycling. (Forti *et al.*, 2020) This is because waste prevention poses its own challenges, namely in how to measure and report progress in the area, as well as how to align it with stakeholder interests, as historically the growth of GDP and waste have gone hand in hand (Bartl, 2014).

One of the most significant e-waste policies is the European Union's Waste Electrical and Electronic Equipment (WEEE) Directive from 2002. It aims to reduce the adverse effects of WEEE by placing the financial responsibility for waste on the manufacturers and distributors of the equipment. The directive requires a separate collection for e-waste from other household waste and sets targets for the collection, recovery, and recycling of waste. The first directive was recast in 2012 with higher recycling and collection rate targets. (Directive 2012/19/EU, 2012)

The directive was direly needed, as Europe generates more e-waste than any other continent at 16.2 kg per capita. It seems that the directive is also working, as the continent of Europe, including non-EU countries, has the highest recycling rate for e-waste (42.5%, followed by Asia at 11.7%). However, this is still far from the goal since the EU collection rate ranges from 12% in Malta to 82% in Estonia, and the only countries reaching the legally binding target of 65% are Estonia and Bulgaria. (Forti *et al.*, 2020) Additionally, while the directive emphasises the importance of waste prevention by reuse and ecological design, no targets are set for these factors, as noted by Bartl (2014).

The UN has also included the topic of e-waste in the work plan for the 12th sustainable development goal (SDG), "responsible consumption and production". Target 12.5 outlines that waste generation, especially regarding WEEE, should be substantially reduced through prevention, reduction, repair, recycling, and reuse. (Forti *et al.*, 2020)

Most contemporary legislation regarding e-waste is focused on promoting recycling instead of reducing waste (Forti *et al.*, 2020). However, more and more global policies are considering more upstream aspects and moving towards a circular economy. Geissdoerfer et al. (2017) define circular economy as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling." The concept of circular economy is focused on the problem of linear and open-ended consumption on a planet that works in a circular and closed system.

Notably, the EU, China and Japan all have national policies for the promotion of circular economy, as well as many countries in Latin America, Africa, and Asia (Chatham House, 2021). The most ambitious legislative policy might be the new Circular Economy Action Plan (CEAP) that the EU adopted in 2020 as part of the European Green Deal (2019). The EU considers circular economy a prerequisite to achieving climate targets and is also pushing for a global alliance in circular economy. (European Commission, 2020)

Durability and repairability specifically are also promoted by various EEA countries. The Ecodesign Directive (2009) of the EU promotes energy efficiency and durability in product manufacturing with longer lifecycles being an important goal. In 2015, France became the first country to make the practice of planned obsolescence illegal. Many EEA countries also offer extended warranties for products to encourage repairing and durability. (Maitre-Ekern and Dalhammar, 2016)

4.2 Recycling as part of the puzzle

Most policies, and companies, seem to focus on promoting recycling. Despite this, according to the UN Global E-waste Monitor only 17.4% of all global e-waste in 2019 was documented to be collected and properly recycled. The recycling rate is not keeping pace with the growing numbers of waste either, as the amount of recycled e-waste has grown annually by 0.4 Mt, while the total amount of e-waste has grown by 2 Mt. (Forti *et al.*, 2020) This is also shown by the fact that from 1990 to 2008, the European Union's recycling rate rose from 13% to 40% (Bartl, 2014), but in 2018, the EU recycling rate was still only 47% (Eurostat, 2021). This is because recycling is faced with multiple issues, which I will discuss in this section.

According to a review on recycling by Bartl (2014), part of the original material is always lost in recycling. For example, aluminium recycled in the USA loses approximately 4% of its content, but the losses may go up to 40%. Despite this, the recycling rate of aluminium is relatively high because the energy demand is lower than for virgin material. Unfortunately, this is not the case for all metals. Bartl quotes a finding by Binnemans et al. (2013), in which out of 60 metals only 13 have a recycling rate of over 50%, and for 57% of metals, including all rare earth minerals, the recycling rate is less than 1%. Another review by Bakhiyi et al. (2018) agrees that more investments in metal recovery are needed, as many recycling technologies are still underperforming and/or polluting.

As for plastics, the loss of properties is an even bigger issue, and contaminants can also remain in the recycled material. Bartl (2014) uses PET bottles as an example, as they must be covered with a layer of virgin plastic before they can be reused. Most of recycled PET is used by the fibre industry, but even then, virgin materials are needed because of degraded material properties. Still, PET is better for recycling than most other plastics, which often contain a mixture of numerous different polymers. This is why incineration can be a better way to recover energy than recycling for plastics. (Bartl, 2014)

Further, Bakhiyi et al. (2018) observe that the cost of recycling has been increasing as a result of more complex material mixtures used in recyclable products, while the value of recycled products has stagnated. Components such as LCD screens and printed circuits cause challenges because of their complexity, hazardous materials, and inefficient recycling technologies, and recyclers might even refuse to process them (Bakhiyi *et al.*, 2018). The problem is only getting worse as technology becomes smaller and more complex, with the number of chemical elements needed increasing (Bartl, 2014).

In the UN e-waste report, Forti et al. (2020) note that because most products are designed without accounting for their recyclability at the end of life, recycling is often a difficult process. The high cost of recycling also comes with social issues, as it makes non-compliant recycling more profitable than controlled recycling. This exacerbates the environmental and health issues that e-waste causes. (Forti *et al.*, 2020)

Despite the challenges, there is still value in recycling. E-waste is sometimes referred to as an "urban mine", as it can contain precious and critical materials. The estimated value of raw materials in the e-waste generated in 2019 alone was $57 billion USD, most of which comes from iron, copper, and gold. The value of the 9.3 Mt of e-waste that was recycled in 2019 was $10 billion USD. As the amount of e-waste generated is only estimated to grow, investing in recycling will be essential. (Forti *et al.*, 2020)

According to the UN report, the urban mine of e-waste could act as an important source of secondary materials in a circular economy. It could mitigate some of the problems of using primary materials, such as price fluctuations, scarcity, and availability. Recycling could be economically viable especially for products containing high amounts of precious metals. However, a circular system could not be supported by recycled materials alone if the demand for materials remains as high as today. Even if all the iron, copper, and aluminium in e-waste in 2019 was recycled, a third of the yearly demand for these materials would have to be supplied from virgin sources. (Forti *et al.*, 2020)

Therefore, recycling by itself is not a practical way to deal with the problem of obsolete technology, and focus should be moved in the direction of waste prevention. Nevertheless, as we are far from a waste-free society, recycling remains an important part of solving the e-waste issue. This means that both recycling technologies and the recyclability of products needs to be improved.

4.3 Longer lifetimes for products

Cooper (2005) highlights the importance of lengthening product lifespans to combat the problem of overconsumption. He considers intrinsic durability and repairability to be necessary solutions. Belkhir and Elmeligi (2018) also found product lifetimes to play an important role in emissions, and they recommend extending the useful life of smartphones to over 4 years. But while it is clear that fewer products results in less waste and emissions, product durability comes with its own problems.

The obvious problem with long-lasting products is that they lead to decreased consumption – after all, the purpose of planned obsolescence is to induce economic growth and generate continuous profits. Thus, product durability poses the risk of unemployment and recession. Cooper (2005) suggests that increased repair and maintenance work could offset the effect on employment, and “green growth” through eco-efficiency is needed to balance out the effect of reduced consumption. There might be some problems with these proposals, however. The amount of repair work generated by increased repairability might not offset the impact of reduced consumption, especially considering population growth and the geographical locations of these jobs. Additionally, the concept of “green growth” through eco-efficiency relies on technological advancements which might not become reality at a sufficient scale.

Another problem with more durable products is that when considering the whole lifecycle, newer products might have an overall lower environmental cost, because for some products the biggest impact is energy during use. One example is CRT monitors being replaced by LCD monitors: the former’s lifecycle annual CO_2 footprint is 79-135 kg and the latter’s 37-62 kg, and CRT’s annual usage can cost as much as the production of an LCD (Belkhir and Elmeligi, 2018). Therefore, better energy efficiency should perhaps be prioritized over longer lifetimes in some cases. In practice, it is unclear which products this applies to because of the challenges in evaluating product lifecycles (Cooper, 2005).

Aside from the problems with economics and lifecycle impacts, there is also the problem of technological and psychological obsolescence. As Cooper notes in an earlier study (2004), consumers adjust their expectations for product lifespans according to technological advancements. The study found that especially computers and mobile phones are likely to be discarded when they are still functional, underlining the impact of technological obsolescence. Some of the survey participants also replaced appliances for aesthetic reasons, or for fear of negative reactions from other people. In the same vein, participants were not always willing to pay more for longer-lasting products, often for concern of the product becoming out of date. (Cooper, 2004)

A similar study in Brazil by Echegaray (2016) found that product lifetimes do not influence consumers’ purchase decisions or greatly affect performance satisfaction. Based on participant reports, 47% of electronic products were discarded while they were still functioning, which underlines consumers’ desire to self-actualize through products. Similarly to Cooper’s study (2004), participants were satisfied with shorter lifespans for smaller and portable devices. While some expressed a wish for longer-lasting products, this was not reflected in their own management of product lifetimes. (Echegaray, 2016)

A study by Cox et al. (2013) likewise found that consumers do not necessarily want longer lifetimes for their products, as most study participants felt social pressure to keep their electronics up to date and saw no benefit in longer lifespans. Many products are thrown away when they are no longer wanted because of the affordability of new products and the need to keep up appearances. However, this is not the case for all products.

In the study Cox et al. identified three product classes which differ in the way they are valued and discarded: up-to-date, workhorse, and investment products. Up-to-date products are often status symbols, and they are subject to replacement because of fashion and technological advancements. Workhorse products are expected to be reliable and last in use, and they are not upgraded as often. Investment products are special investments which can hold an emotional dimension and receive great care throughout their lifetime. (Cox *et al.*, 2013)

According to Cox et al., the lifetime of workhorse products, such as fridges, can be extended by better repairability as consumers seem to have no particular desire to replace them often. Up-to-date products such as smartphones, on the other hand, pose the real challenge as they are often regarded as discardable. The solution could be to transform these products into investment products, which tend to involve financial and/or emotional investment, through higher prices or design for emotional attachment. Another possibility for up-to-date products are upgradeable and updateable designs, such as modular solutions. (Cox *et al.*, 2013)

There already exist some modular solutions on the market, and one of the best-known examples is Fairphone. Fairphone models are designed out of modules, which are easy for users to repair or replace by themselves. Instead of releasing new and improved models each year, Fairphone introduces upgrades to their existing models, latest released upgrade being a higher quality camera for the Fairphone 3. They also offer software updates for at least 5 years, as well as an extended warranty of 5 years for their latest model Fairphone 4. (Fairphone, 2021)

Another example is Framework, a modular laptop that can be upgraded and repaired. Framework's DIY model is the only high-end laptop that can be assembled by the user, allowing for different configurations for processor, memory, ports, and other parts. Each laptop part comes with a QR code that can be scanned for information and repair guides, and the only tool needed for repair is a screwdriver that comes with the laptop. Framework is also launching a marketplace for companies and individuals to sell and purchase parts for the laptop. (Framework Computer Inc, 2021)

These companies are just two examples of the growing modular and upgradeable electronics market. Modular solutions could well be a great way to lengthen product lifetimes both through repairability and upgradeability, but it is questionable whether these solutions can pose a real threat to the prevailing culture of disposability.

Repairability is also an important factor in life spans. In the study by Cooper (2004), one third of the broken appliances discarded by respondents were considered repairable. High repair cost was the main factor deterring consumers from repairing their old appliances and incentivizing them to buy replacements instead. The same finding was made by Echegaray (2016) in a similar study. Cox et al. (2013) also named cost a deciding factor in consumers' repairing decisions, along with how much repair could prolong product life and how convenient it would be to get the product repaired. The study participants found all three aspects to be uncertain in nature, resulting in a general feeling of repair being difficult.

There are multiple ways in which companies reduce the repairability of their products either deliberately or unintentionally, such as by restricting the availability of spare parts, creating incompatibilities with similar parts of newer models, and preventing disassembly by using specific tools or gluing parts together (Maitre-Ekern and Dalhammar, 2016; Bakhiyi *et al.*, 2018). Intentionally poor repairability was an issue already in the 1950s, caused by the competition between repairmen and manufacturers (Packard, 1960). This raises an interesting question: if repair by third parties is a loss to the manufacturers, should a monopoly of repair be allowed to the original manufacturer to incentivize them to make longer-lasting products? Considering a scenario where profit is no longer generated by repeated purchases, Apple's repair restrictions might be viewed as a necessity for a company's survival.

A growing movement, "Right to Repair", has risen to address the current issues of inconvenient and expensive repair options. The aforementioned Fairphone and Framework are examples of companies pushing for radical improvements by designing convenient and affordable repair into their product from the start. Bigger companies are also beginning to acknowledge the movement. Apple, who have long defied repairability and fought against right to repair proposals, announced a self-repair program for users in 2021. This could potentially help with affordability, seeing as replacing the back glass of an iPhone can cost up to $599. Microsoft has also agreed to make its products easier to repair. (Olcott and McGee, 2021)

Additional ways to lengthen product life are remanufacturing, refurbishment, and reuse. As an example, printing company Xerox recovers toner cartridges and waste toner for reuse and remanufacturing through their takeback program. Xerox also remanufactures and resells used office equipment and reuses functioning parts from old devices. (Xerox Corporation, 2021) Refurbishment, which refers to repair and resale of used products, has also been on the rise. For example, Apple collects used smartphones, refurbishes them, and sells them. In 2020, they refurbished 10.4 million devices (Apple Inc., 2021).

4.4 Shifting from products to services

As noted in chapter 4.3, making more durable products is not always the answer because of the influence of psychological and technological obsolescence. One proposed solution to this is product-service systems (PSS), which refers to fulfilling customer needs with a joint mix of products and services. While in product-oriented business models profit comes from maximizing the number of products sold, in service-oriented models it is profitable to prolong product life and increase product efficiency and intensity of use (Tukker, 2015). Product-service systems are a type of circular business model, as value creation is based on the remaining value in products after they have been used, with a return flow from customer to producer at end of use (Linder and Williander, 2017).

Tukker (2015) finds in his review that PSS are generally divided into three categories. Product-oriented services refers to additional services offered along with a user-owned product. In use-oriented services ownership remains with the provider, such as in product renting, sharing, pooling, or leasing. Result-oriented services do not involve a predetermined product, rather the client and provider agree on a set result that is then paid for. Subcategories are outsourcing (e.g. cleaning), pay-per-service unit (e.g. paying per wash in laundry), and functional result (e.g. transport). (Tukker, 2015)

Tukker notes that result-oriented services are the most suited to support a circular and resource-efficient economy, as all material factors become costs. Use-oriented services also have potential, especially product renting and sharing, as use intensity of a product increases and need for new materials decreases. Leasing, on the other hand, can have a negative effect by leading to less careful user behaviour. Product-oriented services offer little environmental benefit, as they still incentivize repeat purchases. (Tukker, 2015)

Despite the possible environmental benefits, product-service systems are not widely implemented in B2C business. Linder and Williander (2017) found that validating a circular business model carries more risk than validating a linear business model, because validation requires a second (and third, etc.) sale of the same product, and producer-retained ownership leads to the stock of resources growing during validation time with each additional sale. Linear business model has the edge, as it allows companies to push the risk of ownership to the consumer, or even increase it as is the case with planned obsolescence. While PPS could benefit from reduced costs in manufacturing, differentiation potential, better customer loyalty, improved understanding of customer behaviour, and increased brand protection, the model also faces challenges related to product return flows, cannibalization, obsolescence, tied capital, operational risk, and lack of supporting regulation, among others. (Linder and Williander, 2017)

To a consumer, the possible value of a PSS solution might also be lower than that of an owned product, because consumers value owning things and being in control. Ownership itself contributes to esteem, and thus has intangible value. PSS solutions can be less convenient, and because of high costs of labour and labour taxes also more expensive. It has been suggested that PSS might not break through in the market without legal and political changes, although this might still not work if customer experience suffers. (Tukker, 2015) Psychological factors might explain why service systems such as leasing, renting and pay-per-use are mostly targeted to other businesses.

There are some exceptions, however. Bundles, a Dutch company that offers durable home appliances as a service, is an example of a use-oriented service. A purchase includes the delivery, installation, recycling of the old appliance, and repair and maintenance when needed. The customer pays for the appliance monthly according to their usage (minimum payment 23.20€ for washing machines), with tracking and efficiency tips enabled by IoT. To give the customer more control, the subscription can be ended at any time, although the transport of the device costs extra if the subscription is ended within 5 years. Devices returned to Bundles will be refurbished and reused when possible, thus contributing to a circular economy. (Bundles, 2021)

PSS is also being tested in consumer electronics. Gerrard Street, another Dutch company, offers customers high-end headphones for a fixed monthly fee. Repairs are included, and the headphones have a modular design, making it easy to swap just the one broken part. When the customer returns the headphones, they are either reused or recycled by the company, and returned broken parts are repaired when possible. The company also offers the option to buy the headphones (with free repairs for a lifetime), which might decrease their business risk. (Gerrard Street, 2021)

4.5 Big Tech and obsolescence

There is limited evidence that either consumers or companies make sustainable choices when it comes to product obsolescence. A study by Cooper (2004) found no correlation between consumers showing environmental concern and consumers repairing (instead of discarding) their broken devices, and similarly in a study by Cox et al. (2013) environmental issues were not important factors in making decisions about lengthening a product's lifetime. Echegaray (2016) found that environmental concern moderately increases a desire for longer product lifetimes, but overall consumers lack awareness of the issues caused by short lifespans. In this section I will examine whether big technology companies acknowledge the effects of obsolescence.

I look at six sustainability reports of some of the largest technology companies producing durable goods: Apple Inc. (2021), Intel Corporation (2021), Microsoft (2021), Samsung Electronics (2021), Huawei Technologies Co. (2021), and Sony (2021). Microsoft and Huawei report on the year 2020, the rest report on the year 2021. In Table 1, I have recorded whether the reports addressed some specific topics relating to durable products; for Intel, this means semiconductors, and for others consumer electronics. "/" counts for all mentions of the topic, and "X" marks more strictly which companies are actively taking steps to progress in the area according to the report.

Table 1. Durable goods issues addressed by sustainability reports

	Apple 2021 (USA)	Intel 2021 (USA)	Microsoft 2020 (USA)	Huawei 2020 (China)	Samsung 2021 (Korea)	Sony 2021 (Japan)
Circularity	/	/	X	/	/	/
Lasting Design	/		/	/		/
Modularity					/	
Repairability	/		/	/	/	/
Recyclability	X		X	X	/	X
End-of-life takeback	X		X	X	/	/
Reuse/ Refurbishment	X	/	X		/	

Apple has decreased their absolute carbon footprint through low-carbon materials, energy efficiency, clean energy, and offsetting carbon emissions. Apple invests especially in energy efficiency and materials efficiency. Apple recognizes product longevity to be important for sustainability goals and cites durability, years of software updates (6 years for iOS), and convenient repair services as ways to achieve it. However, there are no detailed plans to improve product lifetime or repairability, the latter being known to be difficult and expensive for Apple products.

Apple's plan for circular supply chains relies on renewable and recycled materials, and they are making strides in recyclability. Apple offers support for recyclers disassembling their products and is actively researching better recyclability via product design and recycling innovations such as disassembly robots. Apple has a refurbishment program, and they recover parts from used products to reuse them. Recycling and takeback programs are offered, but it seems that they are also intended to encourage repeat purchases: "… by building our products to serve more than one owner and encouraging customers to exchange devices for an upgrade, we extend the life of our products".

Intel, the biggest manufacturer of semiconductors, aims for global carbon neutral computing. Their strategy mostly focuses on "the ICT handprint", the idea that technology can be used to reduce climate impacts across the economy, offsetting the footprint of ICT in the process. Intel is also working for greener chemical strategies across technology value chains by improving the lifecycle analysis of chemicals. Intel claims to be taking steps to improve product design to minimize environmental impacts at end of life, but the only active plan for this seems to be to improve the chemical lifecycle analysis. Intel practices recovery and reuse for their product returns, but there is no plan for end-of-life products or improving recyclability, which is notoriously bad for semiconductors. Still, Intel is partnering with PC manufacturers to help advance circular solutions such as reuse and recycling. As for reducing emissions of semiconductors, Intel is improving their energy efficiency and using clean energy.

Microsoft invests in climate technologies, especially carbon removal, as well as renewable energy and circular economy innovations. Their plans rely heavily on carbon offsets and advancements in carbon removal technologies. For example, the Xbox gaming console achieved carbon neutrality via energy efficiency, renewable energy credits and carbon offsets – not circularity. Despite this, Microsoft states that circular economy is both crucial to solving the e-waste problem and a business opportunity, and they plan to accelerate the circular economy through investments and innovation.

Microsoft has a separate report for devices sustainability (Microsoft, 2020). The report identifies important goals to be carbon reduction, designing out waste, extending product lifetime, maximizing energy efficiency during use, and recycling or reusing components at end of life. Microsoft has a "Healthy Design" strategy dedicated to these issues, which highlights using renewable and recyclable materials to achieve zero waste. Because recycling rates can only be increased if products are designed for recyclability, Microsoft aims to make Surface products completely recyclable, their current highest recyclability rating being 95%. Microsoft also calculates circularity scores for their Surface products, now 22-25%, and employs Lifecycle Assessment to guide design. Furthermore, Microsoft extends product lifecycle by providing "years" of Windows software updates, and they have a refurbishment program for PCs, as well as "Circular Centers" for reusing servers and components. They also have both repairability and takeback programs that they are expanding.

Huawei lists reducing their carbon footprint, promoting renewable energy, and contributing to a circular economy as important goals. Huawei invests greatly in clean energy and improving product energy efficiency. They have succeeded in reducing their carbon footprint per sales revenue, but their absolute volume of GHG emissions is steadily rising. Huawei wants to contribute to a more circular economy, but they do not have a detailed plan on this. Huawei claims to be using more eco-friendly materials, reducing their use of raw resources, making durable products that are also easier to disassemble, and expanding their recycling program. They point out the importance of product durability and mention providing users with software updates and affordable repair services. However, Huawei does not give any details about past or future progress in these areas. Huawei also recognizes e-waste as a significant problem and has built a global recycling program, but while Huawei says that "much" of their waste is recycled they do not provide exact numbers.

Samsung's plan for minimizing product lifecycle impacts include resource and energy efficiency, expanded use of clean energy, extended product life through product architecture, repair services and extended warranty, and better e-waste recycling and reuse programs. It appears that most of Samsung's progress has been made in buying renewable energy and improving materials and energy efficiency, especially in packaging. As for advancing a circular economy, Samsung promotes take-back and e-waste recycling programs. Samsung intends to increase their use of recycled plastics, but it has only decreased from 2018, and it seems to be the only recycled material they use for products. Samsung highlights their products' durability and claims to research better recyclability and repairability for products but provides no details. Samsung is expanding the availability of repair services, and some of their products have verified high repairability ratings. Samsung will also expand their software updates to support three generations of Android upgrades, which spans roughly 4 years. Additionally, Samsung identifies one refrigerator model and one air purifier to implement modular design, making it the only company assessed here to consider modular solutions.

Sony sets goals for less energy consumption and GHG emissions during product use. Because most of Sony's product emissions happen in the usage phase, Sony highlights the importance of energy efficiency. Sony invests in quality in their products and strives for long lifetimes by working on preventing the deteriorating of components, as well as by expanding their global repair services. Sony follows the principle of individual producer responsibility, where a producer bears responsibility for its products over the entire lifecycle. Sony has product takeback and recycling programs, and their designers are actively working to improve recyclability and repairability in cooperation with the recycling business. However, in their own products they only make use of recycled plastics, and there seem to be no plans to include other recycled materials, despite plans to stop using virgin materials for key resources.

Similarly to other reports, while Sony recognizes that society must move to a circular economy, their main way of addressing this is by increasing recyclability and green energy. Sony acknowledges that part of their success in minimizing resource inputs in 2020 was because of a decrease in number of units sold, but this is not considered a viable solution to reduce future emissions in the report.

All of the assessed companies intend to become carbon neutral in the future. Most of the companies are already either carbon neutral or on their way there in their operations, but far from it when considering the entire supply chain including product lifecycles. Of the companies reviewed, only Apple, Microsoft, and Sony have goals for achieving carbon neutrality in their product lifecycles. Similarly, most of the companies have Zero Waste goals and plans for their manufacturing pipeline, but not for product lifecycles.

All of the reviewed companies are mainly concerned with clean energy and improving efficiency. This improvement of energy and/or material efficiency is also sometimes called eco-efficiency, and it is a popular strategy for companies because it saves costs and reduces environmental impacts at the same time, turning into revenue. However, as Cooper (2005) notes, eco-efficiency is insufficient as long as consumption is increasing. As an example Cooper refers to a 2002 OECD study which found that electricity consumption increased in the Netherlands by 14% between 1974 and 1994 despite the efficiency of appliances improving significantly. The same phenomenon is apparent in the sustainability reports: while the companies' normalized GHG emissions (adjusted by sales numbers) are going down as a result of increased efficiency, absolute emissions are still going up because of sales growth (Apple being the exception).

When we consider the "rebound effect" of increased consumption nullifying GHG savings, it is apparent that the success of the strategies presented in the sustainability reports rely completely on the advancement of technologies in recycling, clean energy, and carbon removal. When it comes to big technology companies, the ideal Circular Economy runs on recycling. But as shown in chapter 4.2, this is not a miracle solution, and scaling up recycle services will demand considerable amounts of energy.

None of the reports acknowledge the problem of product obsolescence, and while some recognize the impact of product lifetimes on the lifecycle footprint, improvements in product lifetime extension are limited. While all of the companies (except Intel whose products are used as parts for other products) have recycling and takeback programs, these programs are lacking in many countries, especially in Africa and the Middle East. Repair services face the same problem. Many of the companies also claim their quality and damage tests promote product durability, but none of them are actively measuring and lengthening their product lifetimes.

Notably, none of the reports presented service-based or truly circular solutions, and all of the companies' business models depend on repeated purchases now and in the foreseeable future. While Apple states that "what is good for the environment is also good business practice", Microsoft notes that "for Microsoft to do well, we need the world to do well", and Samsung recognizes that "climate risks directly impact our business operations and financial performance", these notions do not seem to apply to the issue of planned obsolescence.

5 Discussion and conclusions

The purpose of the thesis was to examine the state of planned obsolescence in contemporary technology companies and to critically evaluate proposed solutions to the problem. Here, I conclude the key findings of the thesis and implications to practice. I also present the limitations of research and suggest topics for future research.

5.1 Implications to research

Summarizing from Slade (2006), planned obsolescence as a phenomenon was born with the emergence of mass production and consumerism. It has offered, and continues to offer, companies a reliable way to stimulate repeated purchases for durable products, whose profitability decreases with longer lifetimes (Packard, 1960; Cooper, 2004; Guiltinan, 2009). It is therefore no mystery why planned obsolescence continues to be widespread to this day. In an economy that depends on endless growth, planned obsolescence seems like a necessity.

At the same time, it is clear that planned obsolescence exacerbates the environmental problems of the planet by increasing both emissions and waste problems, as evidenced by the reviews by Bartl (2014), Bakhiyi et al. (2018) and Belkhir and Elmeligi (2018), as well as the Global E-waste Monitor by Forti et al. (2020). Shorter product lifetimes lead to increased environmental impacts, not just sales growth. Considering the growing amounts of e-waste and the warming climate, the technology sector should be moving towards alternatives to their reliability on repeat purchases.

Despite the environmental damage, consumers show limited interest in product lifetimes. Studies by Cooper (2004), Cox (2013), Echegaray (2016), and to an extent even Gregson et al. (2007) show that electronic goods have become symbols of status, and products are constantly being replaced for upgraded versions. These studies seem to provide evidence for the assumption, supported by Slade (2006) and Guiltinan (2009) among others, that planned obsolescence is nowadays a question of psychology and technological advancement rather than physical durability, at least for consumer electronics.

Planned obsolescence can be divided into physical, technological, and psychological obsolescence. While it should be noted that the prevalence of physical obsolescence is difficult to study and prove because of lacking historical product lifetime data (Cooper, 2005), it could be argued that technological and psychological obsolescence are more relevant concerns. These forms of obsolescence are especially problematic because while they harm the environment, they seem to benefit both companies and consumers. Technological advancements can improve quality of life, which is why technological obsolescence was viewed in a somewhat positive light by Packard (1960) as a necessity for progress. Meanwhile, psychological obsolescence is deeply tied to identity and does not improve life per se. It appeals to a desire for new things and negates the possibility of social ostracism, as shown by the aforementioned studies on consumer attitudes.

Some solutions that have been proposed to planned obsolescence are better recyclability, longer lasting products through repairability, durability and upgradeability, and shifting to service systems. All of these solutions come with both advantages and weaknesses, and they address the three different forms of obsolescence to varying degrees. All of them make use of the ideas of circular economy, and public policy will greatly impact whether the solutions are adopted on a larger scale. Seeing as waste policies are being increasingly adopted (Forti *et al.*, 2020), and the EU already has an extensive circular economy plan (European Commission, 2020), these solutions can be expected to be further developed and implemented in the future.

Recycling is the easiest solution for business management, as there is no need to drastically change the business model. As seen in Table 1, recycling is the most common way for big technology companies to make product lifecycles more sustainable. However, the circularity achieved with recycling is incomplete and expensive as shown by Bartl (2014) and Bakhiyi et al. (2018), and recycling is not keeping up with the growing amounts of waste (Forti *et al.*, 2020). While the global e-waste problem cannot be solved without recycling, other strategies are also needed to build a sustainable future.

Longer lasting products is the antidote for short product lifespans, effectively reducing the environmental footprint of products. However, long product lifecycles lead to decreased profits for companies, the energy consumption of newer products may be lower (Cooper, 2005; Belkhir and Elmeligi, 2018), and physical durability does not combat psychological and technological obsolescence. Some progress has been made in the area of physical durability, especially considering repairability of products, but more attention should also be given to durable design to tackle psychological obsolescence. It would seem that "workhorse products" benefit most from physical durability (Cox *et al.*, 2013), and products that are more susceptible to psychological and technological factors should focus on emotional durability, for example by employing modular design such as the Fairphone or the Framework laptop.

Product-service systems have the potential for full circularity and saving resources, but as discovered by Linder and Williander (2017), it carries more risk for companies than simply selling products. It might also not be an attractive option to consumers, as they tend to place value in owning things (Tukker, 2015). Two companies utilizing PSS are Bundles, which offers use of an appliance for a monthly fee, and Gerrard Street's "headphones as a service". While there has been some amount of theoretical research on the possibilities of PSS, there seem to be few real-life business cases.

All of the presented solutions, with the exception of recycling, have been mainly tried out by smaller companies and start-ups, with tech giants showing little interest in them. Considering the company sustainability reports in chapter 4.5, it seems that the issue of short product lifecycles has been largely swept under the rug. Companies are investing in clean energy and carbon removal in an effort to offset their emissions instead of reducing them. While circular economy strategies are recognized as valuable, companies are mainly investing in recyclability, and partially in reuse, rather than designing longer lasting products (see Table 1). This suggests that obsolescence is not presently a true concern for management. It also seems that there is little incentive to explore alternative options, as hardly any business cases can be found researching longer product lifecycles and service systems.

5.2 Implications to practice

It is clear that planned obsolescence will not be solved by the private sector. First, there needs to be clear incentives for companies to act more sustainably. Public e-waste and circularity objectives have already moved some companies to the right direction. Recyclability and repairability are being adopted by many companies, at least on paper. However, because of the rebound effect, these efforts will not be enough to save the environment if consumption levels continue to increase. As is, recycling and remanufacturing cannot keep up with consumption, and thus longer product lifecycles must be demanded. Seeing as consumer behaviour drives obsolescence, excessive levels of consumption should be discouraged.

For a sustainable future, companies will need to move away from the model of disposability. Supported by public policy, this might be possible mainly through the solutions presented in chapters 4.2 and 4.3. Psychological factors, which might be the toughest challenge, could be considered by making timeless and more expensive designs, and technological obsolescence could be taken into account with upgradeability. Shifting from depending on physical goods for value to offering services could also be a valid solution, either with product-service systems or a change in product portfolio. Companies should consider investing in these alternative business models to reliably reduce their emissions, instead of focusing on eco-efficiency and carbon offsets, whose success depends on advancements in technology that might never become reality.

5.3 Limitations and future research

The research in this paper has been mainly written from the perspective of the Western world and developed countries, because most research on the subject of planned obsolescence revolves around North America and Europe. In developing nations, there is a bigger market for second-hand electronics, many imported from developed countries. The manifestation of "throwaway culture" might also differ across countries.

Most of the public policies considered in this thesis are European, meaning that only a small portion of global public regulation is highlighted in this paper. This is because the EU has the most prevalent public policies regarding obsolescence, e-waste, and the circular economy. Most of the world does not have circular economy and e-waste laws. Additionally, the planned obsolescence media cases and sustainability reports examined in chapters 3.2 and 4.5, respectively, only represent the largest six technology companies. Other firms might have vastly different approaches to sustainability.

As mentioned previously, most research on planned obsolescence is focused on developed countries. It might be worthwhile to explore how the phenomenon is present in developing countries. It could also be beneficial to look at a wider range of companies. Additionally, during research it became clear that reliable data on product lifespans is lacking, making the effect of physical obsolescence impossible to prove. Collecting objective data on product lifespans could help in this area.

Seeing as technological and psychological factors are at the root of most contemporary obsolescence in the technology sector, these issues deserve more attention. One especially important research topic that has not been sufficiently explored is consumer attitudes towards alternative solutions, such as modularity or product-service systems. There seems to be limited research on consumer attitudes towards obsolescence overall. As for technological factors, especially the link between technological obsolescence and innovation remains largely unexplored, even while technological progress always leads to obsolescence. It could be worth examining how to balance innovation and obsolescence in a more sustainable manner.

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