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Comparison of the Waste Mangement System in Austria and Romania

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Abstract

The purpose of this master thesis is to determine a possible data gap of the disposed E-waste, particularly the waste of large household appliances in Austria as well as a comparison of the waste management system of Austria and Romania. This shall indicate whether Austria, which counts as one of the pioneers of waste management in the EU, needs further optimization of collecting accrued E-waste. Furthermore, it shall reveal different waste management strategies pursued in Romania and Austria.

The methodology of this paper investigates waste management data of large household appliances in Austria. This data is provided by Eurostat, the official statistical office of the European Union. This data is evaluated, analyzed and prepared for further calculations. A calculation model was developed to firstly evaluate the average disposal rate of large household appliances per year throughout their lifespan as well as the amount of waste that is expected to accrue based on the amount of appliances that is put on the market yearly.

The calculation model developed indicated that a large amount of waste shall accrue but does not appear in the statistics provided by Eurostat. Therefore, over 128.000 tons of waste of large household appliances was expected to additionally accrue between the years 2014 and 2018, which is not properly disposed.

This paper provides insight into the waste management systems, particularly Waste of electrical and electronic equipment of Austria and Romania. The results demonstrate that optimization is needed in both countries in order to reach the environmental targets set out the European Union.

Abstract

Die Motivation dieser Masterarbeit war eine Evaluierung einer möglichen Datenlücke von gesammeltem elektronischem Abfall, besonders in Bezug auf große Haushaltsgeräte in Österreich. Weiters sollte ein Vergleich der Abfallsysteme von Österreich und Rumänien gezogen werden. Dies soll klarstellen, ob es in Österreich einen Aufholbedarf bei der Optimierung der Müllsammlung und Verwertung gibt, obwohl das Land als einer der Vorreiter im EU-Vergleich gilt. Außerdem sollen die verschiedenen Abfall-Strategien, die in Österreich und Rumänien verfolgt werden, miteinander aufgezeigt und verglichen werden.

Die Methodologie dieser Arbeit beleuchtet Daten des Abfall Management von großen Haushaltsgeräten in Österreich. Die Daten wurden von Eurostat, der offiziellen statistischen Einheit der Europäischen Union, zur Verfügung gestellt. Die Daten wurden evaluiert, analysiert und für weitere Berechnungen aufbereitet. Ein Kalkulationsmodel wurde entwickelt, um die durchschnittliche jährliche Abfallquote von großen Haushaltsgeräten zu evaluieren. Basierend darauf wird die Menge an Müll, die anfallen sollte, basierend auf der Menge die jährlich auf den Markt gebracht wird, berechnet.

Das entwickelte Kalkulationsmodel zeigte, dass eine große Menge an elektronischem Abfall anfallen sollte, die nicht in den Daten von Eurostat aufscheint. Über 128.000 Tonnen Abfall von großen Haushaltsgeräten sollte zusätzlich in den Jahren 2014 bis 2018, zu dem bereits gesammelten Müll, angefallen sein.

Diese Masterarbeit bietet außerdem Einblick in das Abfall Management System, speziell Abfall von elektrischem und elektronischem Abfall von Österreich und Rumänien. Die Ergebnisse demonstrieren, dass ein Optimierungsbedarf in beiden Ländern von Nutzen wäre, um die Klima-Ziele der Europäischen Union zu erreichen.

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WEEE – Waste of electrical and electronic equipment

EEE – Electrical and electronic equipment

E-Waste – Electronic and electrical waste

EU – European Union

1. Introduction

1.1 Theoretical scope

With increasing population density and ever-growing demands on technology, companies are under constant pressure to bring new innovations and technologies to the market. On the one hand, to meet the needs of consumers and, on the other hand, to remain competitive. New technologies influence society and its actions. The positive effects of electronic equipment on society are undeniable. (Kahhat, Hieronymi, and Williams 2012)

Nevertheless, with each new technology, old technologies are replaced, which shortens the lifecycle of electrical and electronic products and causes greater waste generation. The result is the rejection of up to 1 billion electronic devices in a 4–5-year period. This scrap of electrical or electronic equipment is referred to as E-waste. (Holuszko, Kumar, and Espinosa 2022)

Today more electrical and electronic waste is being produced than ever before. It is the fastest growing waste sector of the European Union. It represents a major challenge for the Union to minimize its environmental footprint and it's seen as an ever-growing global problem. In 2019, up to 53.6 million tons of E-waste was generated and estimations show, that up to 74 million tons of E-waste will be generated by 2030.
Furthermore, discarded electrical and electronic material contains potentially hazardous substances, possibly pollutes the environment and poses health risks to humans affected in the recycling-process. Moreover, many rare metals, necessary for modern technologies, are sourced from countries that do not respect human rights. (*E-waste in the EU: facts and figures (infographic) | News | European Parliament*, 2020)

Therefore, it is important to improve recycling processes, as well as its know-how and support countries with less technical excellence and financial resources in order to slow down or even stop global E-waste flow.

Even though the European Union has set specific targets for its member states to decrease global pollution and warming, its collection and recycling rates differentiate highly. While all member states work towards goals set out by the Union, they work to conquer different struggles. This master thesis will evaluate the differences between the E-waste management processes in the European Union, particularly in Austria and Romania.

Based on the given facts the following research question accrues:

"How big is a possible data gap of E-waste, particularly large household appliances, in Austria and what differences shows the waste management system of Austria and Romania, regarding their recycling processes?"

Even though waste management has been around for several decades and focus of research for many years, the specific attention on E-waste is a rather recent phenomenon. Considering academic research, it has mostly emerged in the 21st century but has been increasing ever since. A lot of academic research is focusing on harmful impacts on humanity and the environment of inadmissible E-waste processes. (Wong *et al.*, 2007; Olowu, 2012) Therefore, this paper shall focus on E-waste streams of Austria and Romania and their recycling-processes to draw a comparison. This shall help to understand the struggles these countries face, such that they can be easier understood and therefore supported with better solutions.

Furthermore, the International Telecommunication Union (ITU), which monitors E-waste closely, states in its report of 2020, that a European citizen generated with 16 kg the world's highest rate of E-waste per capita. Additionally, in 2019 only 17.4 per cent of E-waste was noticed as formally accumulated and recycled. In 2018, the Plenipotentiary Conference, which counts as the highest policy-making body of the ITU, created the global goal to increase the recycling rate of E-waste to 30% by 2023. Considering those facts, it is clear that further research in the area of waste collection and recycling is highly recommended and needed in order to hit the targets. (*Global E-waste Monitor 2020*, 2020)

Electrical and electronic waste poses a big challenge in the European Union. A problem that seems to augment with every year. The biggest amount of E-waste collected in the EU are large household appliances with a rate of 52.7% (*E-waste in the EU: facts and figures (infographic) | News | European Parliament*, 2020). Therefore, this master thesis will focus on waste accrued by large household appliances in Austria as well as their recycling rate. Recycling rates are based on the amount of waste that is collected by each member state. In order to improve recycling rates, it is necessary to improve the collection process. A study of the European Commission on collection rates of waste electrical and electronic equipment states that member states particularly struggle with the high rate of unaccounted equipment. (*Circabc*, 2014)

The recycling rate of E-waste is based on the amount collected by each member state, which means a high recycling rate is only concerning the appliances properly disposed and collected. Nevertheless, the study mentioned above claims that not every product put on the market is disposed properly, hence not accounted.

The database of Eurostat provides information of all the large household appliances put on the market as well as the amount collected and a recycling rate. Therefore, the question arises what happens with the products, that are not properly disposed. If this estimated number of unreported cases exists it is necessary to question whether the recycling rate, mentioned in databases of the European Union, can be considered as a valid measure for sustainability.

1.2 Methodology

The analysis of individual data will represent the foundation of this master thesis. A descriptive analysis of waste management data of Austria shall provide the necessary information to gain enough insight for the field of research.

Raw and individual data will be evaluated, analyzed and assessed using evaluation tools, such as Microsoft Excel.

In order to examine the research question, the data from "Eurostat", the statistical database of the European Union will be collected. The collected data will subsequently thoroughly selected based on the necessary criteria.
The mission of Eurostat is to "provide high quality statistics and data on Europe". (*Eurostat*, 2022)

This database was selected due to its partnership to National Statistical Institutes of member states of the EU. It is also known as the ESS, the European Statistical System, which includes also "statistical authorities of the European Economic Area (EEA) countries and Switzerland". (*Eurostat*, 2022)

Since this master thesis focuses on the waste of large household appliances, the used data focuses on Austria within a time frame of 18 years. A broader scope of time will exceed the scope of this master thesis. The consulted data refers to an annual time frequency and a unit of measure of tons. Consequently, the used data will display all large household appliances, put on the market yearly. Subsequently, data derived from waste management operation will solely focus on the waste collected of large household appliances. The comparison of this data

shall give an indication of an estimation number of a data gap of unreported or irregular disposal of large household appliances. In order to examine the underreportings it is necessary to consider the lifespan of large household appliances. This variable is necessary to examine how many products will accrue every year and compare it with how many are effectively disposed.

Eurostat has already created statistics that visualize the total amount put on market, total amount collected and total amount recycled and reused. Nevertheless, information of the lifespan of electrical and electronic equipment was not available and is, therefore, not considered in the statistics. This factor is inevitably necessary to consider in order to properly examine the amount of waste that must accumulate. (*Waste statistics - electrical and electronic equipment*, 2022)
Furthermore, recycling processes and waste management processes (and prepared for reuse) of large household appliances and E-waste, of two member states of the European Union, will be analyzed. Those two member states are Austria and Romania. After an analyzation of their processes and status quo, they will be compared with each other. The comparison shall provide a better understanding for the struggles the member states have to conquer and provide a learning especially for member states with less mature waste management processes and know-how.

In order to examine aspects mentioned abovice, a calculation model needs to be developed in order to examine the missing gap. This model will be designed via Microsoft Excel and shall consider large household appliances put on the market, their lifespan as well as the appliances, that are properly collected for the years 2005 until 2018.

1.3 Structure of thesis

This master thesis is structured into 7 chapters that contain sub-headings. The first chapter shall present the motivation for this thesis, outline the problem as well as recap the current environmental situation. In its sub-headings this chapter will clarify the theoretical scope and the methodology this thesis will follow. Chapter 2 focuses on the Terminology in a way that any misunderstandings concerning certain terms can be evaded and also provide a clearer insight in which context the terminations will be used. Chapter 3 gives the first insight into the main part of this thesis and provides an introduction into the current situation of E-waste. This offers the basis on which the following chapters will be established on. Chapter number 4

focuses on the calculation model, which is one of the main parts of this work. It shall present a possible data gap in Austria's E-waste management system, more particularly in waste of large household appliances. The following chapter, number 5, explains the recycling methods of large household appliances within the European Union. Furthermore, chapter 6 compares the supply chain, more specifically the recycling system, of waste of electrical and electronic equipment of two EU member states, namely Austria and Romania. The last chapter summarizes the information and the knowledge, detected in this thesis, and gives an incentive for further research.

2. Terminology

Before proceeding with further research of this thesis, the definition of certain terms is required in order to avoid misunderstandings.

2.1 Sustainability

During the past years there has been growing concern about the negative impact that E-Waste has on the environment and our society. The behavior to live a more sustainable lifestyle as well as the concept of sustainability itself has received a lot of attention within the recent years. Global issues, such as pollution, global warming, consumption of finite resources and growing world's population has led to a common understanding for the need of change, especially regarding sustainability. (Hester and Harrison, 2008)

The initial term and the principle of sustainability originally refer to the use of resources and go back to the 18th century. Since then, the term has undergone a more fundamental development, which focuses on a rather ethical and moral approach of shaping the future. (Mayer, 2020)

Sustainability plays a relevant role in all levels of humanity. It starts at a global level and goes as far as the individual level.

The Brundtland Report has defined the term 'sustainable development' as followed:

> *„Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

(Aachener Stiftung Kathy Beys, 2015)

In other words, it refers to a focus on the environment while considering the needs of the present society but not hindering the future society to fulfil their needs. Furthermore, sustainability focuses on three specific components.

- *Social*: it covers all actions that affect the society such as poverty, injustice, public health, violence, or human rights.
- *Economic*: concerns all actions that affect how the economic needs are met with focus on operating profitably.
- *Environmental*: focuses on restoring and protecting the global ecosystem, such as the prevention of toxic waste or the preservation of natural resources.

(CHOUDHURY, 2019)

This Master thesis will only focus on the environmental term of sustainability.

Considering the approach of fulfilling the needs of society without hindering future generations of fulfilling their needs under the same conditions, the three-pillar-concept of sustainable development was developed. They represent the interdependence between economic and social developments in terms of social and ecological development:

- Ethically oriented
- Resource oriented
- Systematically oriented

The goal of these pillars is to achieve an equilibrium. (Mayer, 2020)

2.2 E-Waste

Electronic and electrical waste is one of the biggest challenges the European Union has to face. It counts as one of the fastest growing areas of waste streams and it is constantly increasing at a much higher pace than other waste streams. The ever-growing demands of society for new technologies and the fast-growing industries with arising new technologies and devices has led to smaller lifecycles of electronics. This leads to a higher stream of obsolete products. The accumulated waste paired with the lack of proper end-of-life management option has led to an overall unsustainable management of E-waste. (Herat, 2007)

The European Union classifies the following 10 categories as Waste of electronic and electrical equipment:

“1. Temperature exchange equipment

2. Screens, monitors, and equipment containing screens having a surface greater than 100 cm2

3. Lamps

4. Large equipment (any external dimension more than 50 cm) including, but not limited to:

Household appliances; IT and telecommunication equipment; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control

instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3.

5. Small equipment (no external dimension more than 50 cm) including, but not limited to:

Household appliances; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3 and 6.

6. Small IT and telecommunication equipment (no external dimension more than 50 cm)" (*Waste statistics - electrical and electronic equipment*, 2022)

Large household appliances, such as refrigerators, kitchen stoves and washing machines, account for the largest share of collected E-waste in the EU with 52.7%. IT and telecommunication equipment (laptops, printers), consumer appliances and photovoltaic panels (video cameras, fluorescent lamps) follow with 14.6% and 14.1% respectively in second and third place. Small household appliances are on the fourth place, such as vacuum cleaners, with 10.1%. Only about 40% of the E-waste collected in the European Union is recycled. (*E-waste in the EU: facts and figures (infographic) | News | European Parliament*, 2020)

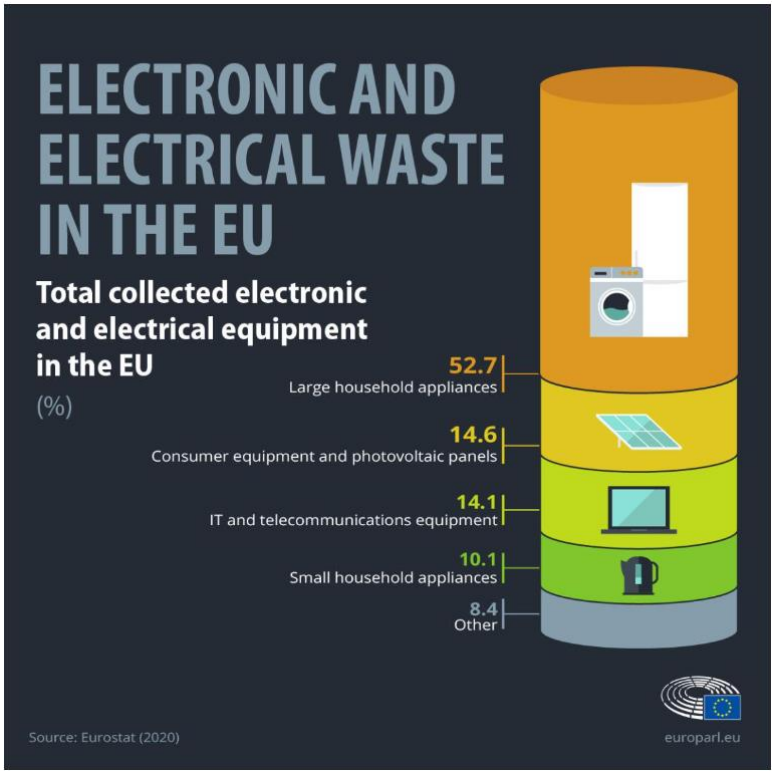


Figure 1: Electronic and electrical waste in the EU, 2020

However, those figures only represent the amount of E-waste collected. A significant portion of this waste is not collected and, therefore, it does not appear in certain statistics. This E-waste is potentially disposed in landfills or exported to third-world countries. The collected high-value materials are often fed back to the manufacturing process, whereas low-value materials are frequently abolished in landfills. In order to boost the circular economy, the proper collection of E-waste must be increased. Furthermore, the recycling processes, as well as the processes for reuse, need to be studied further such that the fractions of disposed materials could be minimized. (Holuszko, Kumar and Espinosa, 2022)

Additionally, discarded electric and electronic equipment may potentially contain hazardous components, that pose health risks for humans affected in the waste management processes and may pollute the environment. Furthermore, rare metals which are necessary in the production process of modern technologies are often sourced in countries not respecting human rights. (*E-waste in the EU: facts and figures (infographic) | News | European Parliament*, 2020)

Although E-waste is often categorized as dangerous waste, it has great potential for value recovery in the recycling process. It consists of many valuable and precious materials such as iron, gold, copper, silver, platinum, etc. Therefore, it provides materials worth remanufacturing, refurbishing and recycling. In 2013, for example, 11% of the global gold production (2,770 tons) was dismantled from mines whereas almost 300 tons of gold were recycled from E-waste in 2014. E-waste can be recycled by formal and informal procedures. Through manual recycling the release of toxins and persistent organic pollutants harmful to the environment and the people embedded in the recycling process are inevitable due to the usage of primitive techniques. (Prasad, Vithanage and Borthakur, 2019)

2.3 Large household appliances

To create a more profound understanding of the term “large household appliances” we need to clarify the appliances that fall under that category. Large household appliances are often referred to and understood as “white goods”.
Donald F. Blumberg categorizes large household appliances in the year 2014 (white goods) as the following:

-Washers
-Dryers

-Ranges
-Dishwashers
-Microwave oven
-Air conditioners
-Garbage disposals

(Blumberg, 2004)

A more recent classification of 2023 of Statista, a leading provider of market and consumer data, classifies large household appliances as the following:

-Washing machines
-Refrigerators
-Dishwashers
-Hobs
-Built-in ovens
-Microwave ovens
-Hoods
-Tumble dryers
-Free-standing cookers
-Freezers

(*Europe: major home appliances unit sales 2016-2021*, 2022)

2.4 WEEE- Management

The WEEE Directive in Europe was implemented to reduce the negative environmental and health impacts from increasing e-waste. The goal was to improve the recovery of valuable materials and substances. (Goodship, Stevels and Huisman, 2019)

The term WEEE is an abbreviation of "Waste electrical and electronic equipment". Article 3(1)(a) of Directive 2012/19/EU describes electrical and electronic equipment (EEE) and other concepts for monitoring WEEE management as follows:

- "'*electrical and electronic equipment' or 'EEE' means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed*

for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current."

Waste of electrical or electronic equipment (WEEE), therefore, means all the equipment which is considered waste within the meaning of Article 3(1)(a). It also includes all "components, sub-assemblies and consumables which are part of the product at the time of discarding*."*(*Waste from Electrical and Electronic Equipment (WEEE)*, 2022)

The origin and the manufacturer, the large number of electric and electrical appliances as well as the year of the production makes WEEE material composition variable and, therefore, hard to generalize. Nevertheless, the dominant material fraction are metals which cover over 60% by weight. WEEE can be considered an "urban mining" process due to its valuable components. ('WEEE management in a circular economy perspective: an overview', 2018)

3. E-waste in the EU

All electronic and electrical waste may contain potentially hazardous substances that endanger the environment as well as humans. It is necessary that those hazardous components are removed (stripping). During the stripping process it is essential that highly contaminated components will not appear in fractions held back for recycling. (Hung *et al.*, 2017)

3.1 Treatment strategies of E-waste

Developed countries, such as North America or Europe, produce the most amount of E-waste. Much of this E-waste is not disposed in the countries themselves, but ending up in developing countries. In 2012, about 70% of the world's E-waste was disposed and processed in China. The rest went to India and other developing countries, such as eastern Asia and Africa. (Wang, Zhang and Guan, 2016)

The global challenge of E-waste is mostly due to the unsustainable processes, in which way electronic devices are produced, consumed and disposed. If those processes would be handled sustainably and consciously, the current environmental crisis and global warming could be reduced drastically. Nevertheless, social differences as well as cultural beliefs and values make coherent strategies and regulations almost impossible to adopt in different countries. (Andeobu, Wibowo and Grandhi, 2021)

Limited policies, legislation and precautions, imported E-waste and E-waste from second-hand have led to ecological problems and human hazard in many countries. The reason for these comprise in primitive techniques, such as melting plastics, chipping, open pit acid baths or stripping of metals without adequate ventilation. Other techniques, such as dismantling devices and burning cables open air are used at informal E-waste recycling sites. Numerous studies have shown, that the toxic waste of E-waste recycling processes has direct impact on the environment, as well as human health. (Prasad, Vithanage and Borthakur, 2019)

Nowadays, recycling practices and technological advances have been mandatory for global and domestic E-waste recycling. It is mandatory in order to reduce the social and environmental burden, manage all resources efficiently and last but not least, work economically. (Rene *et al.*, 2021)

Dismantling, processing and end processing are considered the typical treatment processes for E-waste. Dismantling is the fundamental step to separate hazardous as well as valuable

elements from one another. Secondly, components are fragmentized such that compounds can be separated. End processing is considered a process at which non-metal and metal fractions are ultimately further processed. All processes vary for each product category. The treatment for large household appliances, starts, among others, with the elimination of hazardous elements by dismantling. Secondly, mechanical processing is used by shredding and different separation technologies such as magnetic separation.
E-waste management in Europe has adopted the already existing structures from municipal waste management. The main challenge the European Union must tackle are the intensification of the collection and the confinement if illegal exports. Furthermore, the EU struggles to introduce uniform standards, such as technical as well as monitoring standards. Those standards shall simplify the treatment of E-waste throughout all member states of the European Union. (Salhofer, 2018)

The collection rates of E-waste within the European Union vary from one country to another. Those meanderings can be explained by the type of waste management organization as well as the development stage of collection plan. Importantly, it must be said that the reference for collection rate is only estimated. The lack of harmonization is based on fundamental differences across all member states of the European Union. (Horta Arduin *et al.*, 2019)

Due to the resource potential of WEEE, it has been considered a lucrative business model in developing as well as developed countries. Nevertheless, the complexity of E-waste and the low concentration of high value materials lead to a high treatment cost if all health and environment standards are met. Consequently, recycled materials such as polymer resins may result in higher costs than the correspondent raw material. (Horta Arduin *et al.*, 2019)

The European collection channels for E-waste vary based on the location of pre-processing, on volumes and logistic costs. The main collection channel for household WEEE are municipal waste collection centers. After the collection the waste is transported to regrouping centers and ultimately delivered to several waste treatment facilities. At these stations they undergo different operational steps, depending on the waste stream. (Horta Arduin *et al.*, 2019)

3.2 Treatment of large household appliances

Since large household appliances account with approximately 52% of all the E-waste as the largest part within the European Union, it is the focus of this thesis.

Household appliances, such as washing machines, cookers, cleaning appliances, electrical heaters or ventilators, fall under the category large electrically powered waste appliances. Those appliances consist mostly of aluminum, copper, iron and certain insultation materials, which are mainly inorganic. Electronic controllers of those appliances are considered scrap, due to particularly hazardous elements, such as batteries, mercury switchers, etc.
The goal of the disposal of large household appliances are broken down to the following steps:

(1) Stripping of potentially hazardous substances

(2) Tapering of hazardous substances in the shredder residue

(3) Recovery or recycling of ferrous metals

(4) Obtainment of recyclable scrap quality.

(Hung *et al.*, 2017)

3.3 Circular economy

We live in a linear economy. All the products produced in the world are designed to be used and subsequently thrown away. Our society is consume-oriented. The demand to produce more and better products is high. But it is not only depending on the demand of consumers, but also necessary for our economy to thrive. Nevertheless, what seems to be working for the economy does not well work for the environment. Ecosystems are being destroyed, polluted, and contaminated. Regardless, economic players have neither the urge nor the simple interest to bring durable and sustainable products of recycled materials to the market, since it could derogate their revenue. (Jensen, 2015)

Nevertheless, a change of mindset is required in order to countervail the exploitation of natural resources. The ultimate goal of working sustainably needs a resourceful utilization of materials and a shift of lifestyle in consumer behavior. That means a reevaluation of the lifecycle of products is necessary. The lifespan of products needs to be expanded and resources of discarded products need to be re-used or recycled as long as they can be

beneficial. In a circular economy, resources, products and materials shall be retransferred into the Supply Chain, such that the formation is minimized as much as possible. Firstly, the transition towards a circular economy means that values of resources, materials and products are retained in the economy as long as possible. Secondly, the overall waste generation needs to be minimized which will ultimately lead to social, economic and environmental benefits and gains. (Czaga, 2017)

The European Commission has adopted an action plan in March 2020 to implement the circular economy within the EU. It represents one of the main pillars of the European Green Deal, which is the EU's agenda for sustainable development and growth. This plan represents a transition into an economy with less pressure on resources and shall furthermore, create jobs and a sustainable development and growth within the European Union. Additionally, it shall also help to achieve the Unions target of climate neutrality (2050) and retain further loss of biodiversity. This action plan comprises initiatives along the whole lifecycle of products. It approaches the design of products, enforces sustainability of consumption, assures to prevent mass waste production and holds resources in the European Union's economy for as long as possible. (*Circular economy action plan,* 2022)

Balancing the lifetime and energy efficiency of products the European Union implemented the "Energy Label" as a concept of circular economy with the aim of reducing overall energy consumption. This scheme was implemented on electric and electronic devices in order to rank the energy efficiency of appliances on a scale. The scale ranges from A (green), which labels energy efficient products, to G (red), that labels a rather inefficient use of energy. Rather recent circular economy models focus on leasing large household appliances with pay-per-use systems. Those models should encourage households, policymakers and citizens towards a more environmentally friendly production as well as sustainable energy consumption. 85% of European consumers recognize this labeling system when purchasing household appliances. Therefore, it has not only been considered a success but also encouraged innovation industry development. (Alejandre, Akizu-Gardoki and Lizundia, 2022)

4. The calculation model

This master thesis is based on data analysis as well as a comparison of the recycling system of two member states of the EU. As already stated in the introduction, the analysis Austria's data is a suitable research method when it comes to understanding the waste disposal system of large household appliances as well as evaluating the status-quo of waste management within the EU, particularly Austria and Romania.

In order to examine the research question: *"How big is a possible data gap of E-waste, particularly large household appliances, in Austria and what differences does the waste management system, with regards to recycling processes, of Austria and Romania hold?"* it is important that all the necessary data is selected, adequately compiled and analyzed. The relevant data will be analyzed through Microsoft Excel and visually customized.

A quantitative approach is used to examine the research question. This method has proven to be useful in order to elevate and execute data in a practical context of research.

4.1 Criteria for data collection

In order to examine the research question a databank with respective data of the European Union was considered. This databank is accessible free of charge and provided by Eurostat, which is the official statistical office of the European Union. The department "Environmental statistics and accounts" as well as "sustainable development", based in Luxembourg, is relevant for this thesis. The consulted data is based on waste of electric and electronic equipment collected on the European Parliaments basis of "Directive 2012/19/EU" and of the Council of 4th July 2012.
Monitoring the compliance of member states of the European Union with targets of collection, preparation, preparation for re-use as well as recycling and recovery of electric and electronic waste is the purpose of the data collected of Eurostat. The original data is collected by the member states. The assembled country compilations are checked and collected by Eurostat. Quality assurance and proper documentation falls under the responsibility of both, the member states and Eurostat. (*Waste electrical and electronic equipment (WEEE) by waste management operations (env_waselee)*, 2022)

4.1.1 Basic data

As the official statistical office of the European Union, Eurostat provides high-quality data and statistics of the member states. A partnership with national authorities of the member states as well as National Statistics Institutes allows to receive reliable data on WEEE. (*Eurostat*, 2022)

Environmental Protection Agencies, Ministries of Environment and national statistics institutes collect relevant data from several sources such as:

- Exporting and/or importing businesses as well as producers
- Administrative sources: waste treatment facilities, waste collectors, local authorities and municipalities

The data is collected annually and is submitted by reporting countries via a webform called "Edamis". The unit of measure used for the analysis of data is 'tons'. This unit was chosen as the most suitable comparison of the average waste streams of Austria. (*Waste electrical and electronic equipment (WEEE) by waste management operations (env_waselee)*, 2022)

The data relevant for this thesis is consulted in the timeframe of 2005 until 2018. Only the consultation of a broad timeframe allows a proper evaluation of the research field as well as the research question. However, the database of Eurostat only allows access to data until 2018.
Furthermore, in order to examine the dark figure of waste of large household appliances that is not properly disposed, it is necessary to consider the average lifespan of these products. With knowledge of the lifespan and the amount that is put on the market yearly we are able to acquire information about the absolute amount of replaced appliances. Thereafter, we can compare the expected amount of waste with the actual amount of disposed appliances and identify if waste exists failing to appear in statistics.

The basic data for the lifespan of large household appliances will be drawn by the General Federal Environmental Agency of Germany. This data will be considered as valid for products put on the market in Austria.
Data on large household appliances put on the market as well as data on how many products are disposed every year was made available by Eurostat, the official statistics office of the European Parliament.

Therefore, the analysis of data is based on the following:

- Country, waste category, unit measure, waste management operation, year

(*Waste statistics - electrical and electronic equipment*, 2022)

The comparison of the number of appliances put on the market and the number of disposed appliances shall give an indication about those appliances that were not properly collected. A recycling or preparation for re-use process can only be initiated with orderly collected products. To draw a conclusion, other factors, such as the average lifespan of large household appliances, must be considered.
The office of statistics of the European Parliament has released statistics stating the amount of products put on the market as well as the amount of waste collected. The description states, that the average lifespan of the products was not available and, therefore, not considered in the statistics. However, the lifetime of those products is a factor that must be considered inevitably in the calculation to determine how many products must accrue at the end of their lifetime or end of usage. Only the lifetime and the number of products put on the market every year can give an orderly approach of how many products shall accrue yearly. This number shall be compared with the total amount collected and give an indication about the waste that is not orderly disposed. Therefore, this results in a possible data gap of E-waste in Austria.

For the analysis of the data Microsoft Excel, a designated analytics tool, will be consulted. Microsoft Excel has proven to be a proper tool to gather, structure and analyze data. Furthermore, it allows operators to visualize data in several forms. Furthermore, it is a tool which is integrated in the Microsoft office package and accessible for all Microsoft users.

Secondly, the analysis of the recycling system for E-waste shall provide an understanding of the differences in the maturity of the supply chain management of member states of the EU that work towards common goals set out by the EU. For this, the waste management process of waste of electrical and electronic equipment of Austria and Romania is analyzed, evaluated and compared.

4.1.2 Data availability and assumptions

Lifespan of large household appliances

In order to calculate the absolute amount of large household appliances that are at the end of their lifetime or replaced every year, we first need to evaluate an accurate approximation of the disposal rate. This data is not yet available or easily accessible for the European market. Based on the share of appliances that are replaced every year and the amount of products that are put on the market we can calculate an approximation of waste that must accrue every year and compare it with waste collected in Austria. This will give an indication of a data gap of not properly disposed large household appliances.

The General Federal Environment Agency of Germany conducted a study on large household appliances in 2015.
The Federal Environment Agency is a scientific authority of Germany and holds over approximately 1,700 employees that evaluate and observe the status quo of the environment. (Redaktionsassistenz 1, 2013)
The study includes the failure quota of large household appliances as well as a possible planned obsolescence of manufacturers. The study contrasts the share of failure of appliances in the years 2004 and 2012/13 and shows a significant rise in failure quota as a comparison in those two timeframes (see figure 2). Since the basic data, which is drawn as a foundation of this thesis, of large household appliances of the European Parliament (Eurostat) comprise data starting with the year of 2005, data of the lifespan of large household appliances will be considered of both timeframes. This data is mathematically condensed and accumulated over the years through a moving average.

The study was conducted from a German scientific authority and will be considered for all large household appliances used in Austria, since manufacturers distribute their products internationally rather than locally. Therefore, it will be considered a valid source for the lifespan of all large household appliances put on the market in Austria.

The study of the lifespan of large household appliances of the Federal Environmental Agency focused solely on the period of the first usage to the purchase of a replacement product. It did neither include the possibility of a secondary use in any kind nor the case of usage after repair. (Rathmann, 2015)

4.2 Approach of data comparison

The data is derived from Eurostat und converted into an .xls format. Since this data format is disordered and not functional for further evaluation and analysis, the first step is to bring it into an appropriate format.

The first comparison consists of all large household appliances brought to market and the waste collected within Austria.
In order to examine the dark figures of yearly waste of large household appliances we need to consider the share of products that need to be replaced every year. Based on the share and the amount put on the market, we can evaluate the absolute amount of products that need to be disposed.

This model is only executed for Austria.

For this calculation model it is necessary to understand that waste of products put on the market accumulates not only for the same and the following year but also from the years in the past, since the lifetime reaches up to over ten years. That means, that each year a certain amount of waste is generated. This waste compounds of waste of products put on the market in the past, due to their lifecycle reaching several years.

This shall show the development of obsolescence throughout the years as well as an indication of a possible data gap of waste of large household appliances.

As a next step the waste management processes of E-waste within Austria and Romania will be compared. Thereafter, the waste management part of the supply chain will be examined and shall provide a basis of understanding how member states function and how their processes still differ even though they are working towards the same targets set out by the European Union.

4.3 Data model

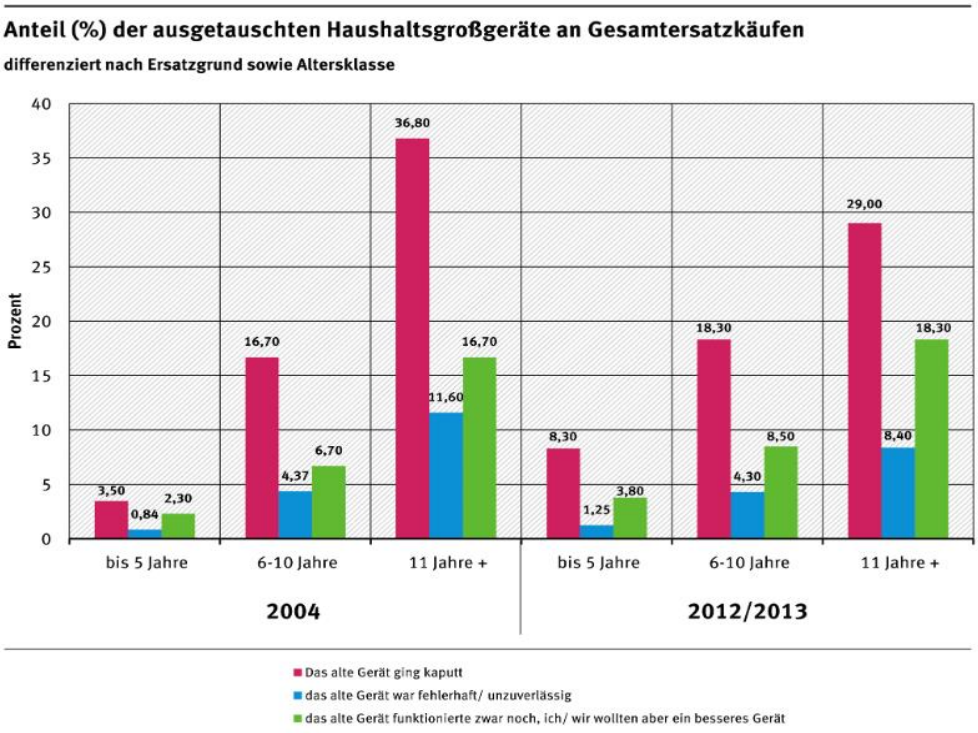
4.3.1 Lifespan of large household appliances

The lifespan of recent products with more modern technology that are put on the market is less due to different reasons. The study distinguishes three categories or reasons of product failure in certain timeframes. The timeframes enclose the share of exuded

products within the years 0-5, 6-10 and 11+ years for both 2014 and 2012/13. Furthermore, the reason of exsolution was examined and encompasses three reasons for replacement:

- the old appliance was broken,
- the old appliance was defective,
- the old appliance was still working, but a better one was required. (Rathmann, 2015)

All the reasons of excretion mentioned will be considered in further calculations of this thesis.



(Rathmann, 2015)

Figure 2: Share (%) of large household appliance replacements in total replacement purchases, 2015

For further calculations a model was created to determine the exact rate of products that will be replaced and therefore accrue as waste. This was necessary to combine the two timeframes of the study as well as to smoothen the curve from a stepped to a smooth slope.

4.3.2 Moving average

The moving average of a time series eliminates fluctuations by averaging relatively low values and relatively high values to an average level, such that the curve is smoothened. This is necessary for the evaluation of a trend development. (Matthäus and Schulze, 2007)

A moving average was necessary for this calculation in order to detect a smooth progression of replaced/broken products.
Figure 2 shows the share of replaced products throughout the years of usage of large household appliances. This study offers the basis for further calculation. In order to evaluate the share of products that need to be replaced every year, those figures need to be spread evenly throughout the years. This means that the broken products that accrued in the first five years (2014) result in 3,50% which is evenly divided for every year, such that 0,7% accrued in 2004, 2005, 2006, 2007, 2008.

Furthermore, the moving average needs to be calculated in order to smoothen the curve and to evaluate the approximation of the share of replaced products.

Through mathematical interpolation a distribution factor was calculated.
The function $y = 0{,}8967e^{0{,}2038x}$ was derived from the calculation of the moving average.
This was inserted in the following Excel calculation in order to receive the distribution factor the curve needs to have.

=0,8967*EXP(0,02038)*1,328 => Factor 1,2

The calculation was executed with the following intention:

Distributions of appliances' lifespan share from 2004 until 2011

years	2004	2005	2006	2007	2008	2009	2010	2011
broken	0,7	0,7	0,7	0,7	0,7	3,34	3,34	3,34
faulty	0,168	0,168	0,168	0,168	0,168	0,874	0,874	0,874
better products	0,46	0,46	0,46	0,46	0,46	1,34	1,34	1,34
Sum of replaced products	1,328	1,328	1,328	1,328	1,328	5,554	5,554	5,554
Distribution	1	1,2	1,44	1,728	2,0736	0,65	0,78	0,936
correction								
Distribution over the years	**1,3**	**1,6**	**1,9**	**2,3**	**2,8**	**3,6**	**4,3**	**5,2**

Table 1: Share of appliances' lifespan 2004, distribution over the years, calculation model

Distributions of appliances' lifespan share from 2012 until 2023

years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
broken	1,66	1,66	1,66	1,66	1,66	3,66	3,66	3,66	3,66	3,66	5,8	5,8
faulty	0,25	0,25	0,25	0,25	0,25	0,86	0,86	0,86	0,86	0,86	1,68	1,68
better products	0,76	0,76	0,76	0,76	0,76	1,7	1,7	1,7	1,7	1,7	3,66	3,66
Sum of replaced products	2,67	2,67	2,67	2,67	2,67	6,22	6,22	6,22	6,22	6,22	11,14	11,14
Distribution	0,9	1,008	1,12896	1,2644352	1,4161674	0,7	0,798	0,90972	1,0370808	1,1822721	0,75	0,855
correction												
Distribution over the years	**2,4**	**2,7**	**3,0**	**3,4**	**3,8**	**4,4**	**5,0**	**5,7**	**6,5**	**7,4**	**8,4**	**9,5**

Table 2: Share of appliances' lifespan 2012, distribution over the years, calculation model

First, the broken, faulty products and replacements for better products are summed up and spread over the years (1-5; 6-10; 11+). Secondly, a function was derived from this value to identify the distribution of the share over the years.

This calculation offers an accurate approximation of the share of large household appliances that are replaced every year.

Since the study of Rathmann, 2015 (see Table 2) shows that appliances put on the market in 2012/13 have a lower lifespan, the two calculation periods are merged into one calculation model.

	2004 investigation of lifespan												2012 new investigation of lifespan												
Distribution of lifespan	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	Monitoring
Large household appliances	1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%										100,00 %
Large household appliances		1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%									100,00 %
Large household appliances			1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%								100,00 %
Large household appliances				1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%							100,00 %
Large household appliances					1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%						100,00 %
Large household appliances						1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%					100,00 %
Large household appliances							1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%				100,00 %
Large household appliances								1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%			82,18 %
Large household appliances									1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%		67,55 %
Large household appliances										1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	17,8%	55,37 %
Large household appliances											1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	14,6%	45,21 %
Large household appliances												1,3%	1,6%	1,9%	2,3%	2,8%	3,6%	4,3%	5,2%	6,2%	7,5%	8,5%	10,2%	12,2%	36,75 %
Large household appliances													2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	5,0%	5,7%	6,5%	7,4%	8,4%	9,5%	36,69 %
Large household appliances														2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	5,0%	5,7%	6,5%	7,4%	8,4%	30,24 %
Large household appliances															2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	5,0%	5,7%	6,5%	7,4%	24,58 %
Large household appliances																2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	5,0%	5,7%	6,5%	19,62 %
Large household appliances																	2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	5,0%	5,7%	15,27 %
Large household appliances																		2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	5,0%	11,48 %
Large household appliances																			2,4%	2,7%	3,0%	3,4%	3,8%	4,4%	8,11 %

Table 3: Share of replaced products over the years, two timeframes, calculation model

Due to the lifespan of large household appliances, they only get disposed after a certain period. The disposed equipment which is put on the market in a certain year is spread over a period, since not all products break or get replaced at the same time. Therefore, appliances that are put on the market years ago could possibly still be in usage, hence, not 100% of those

products accrue as waste at the same time.
Since the statistic of Rathmann 2015 (see figure 2), only starts in the year 2004, it is assumed that starting with the year 2000 the same share of appliances accrues. This assumption needs to be made in order to have a wider data base to draw conclusions for the calculation model. Otherwise, the timeframe would be too small to make proper statements.

4.3.3 Data analysis

Based on the calculated moving average of replaced large household appliances and Eurostat's data on how many products were effectively disposed in Austria, we can evaluate an accurate approximation of the absolute number of products that should be disposed every year. These amounts will be compared with Eurostat's data on how many products are properly disposed. These data sets will be compared and shall give an indication of a possible data gap of how many large household appliances shall accrue (based on their lifespan) and how many are effectively disposed.

Since Eurostat only provides data stating with 2005 on how many products are put on the market every year, we need to make assumptions on the amount of products put on the year before that, starting with the year 2000. Those assumptions are based on the growth rate of the following years and are reckoned back. They are an absolute necessity to draw proper conclusions about how many products must accrue based on the amount that is put on the market.

Table 4 shows the calculation model of the amount that must accrue over the years. The red marked column are the assumptions that needed to be made. These assumptions are based on the growth rate of the following years, that are marked in yellow. The field marked in green shall indicate the year where the calculation differed, since the lifespan of large household appliances changed starting with 2012/13.

Land	Appliances put on Market	year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	accrued appliances in to
Austria	50.000	2000	664,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**664,01**
Austria	52.500	2001	796,8	697,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**1.494,02**
Austria	55.125	2002	956,2	836,6	732,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**2.524,88**
Austria	57.881	2003	1147,4	1004,0	878,5	768,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**3.798,52**
Austria	60.775	2004	1376,9	1204,8	1054,2	922,4	807,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**5.365,32**
Austria	68.411	2005	1805,1	1445,7	1265,0	1106,9	968,5	908,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**7.500**
Austria	74.610	2006	2166,1	1895,3	1518,0	1328,2	1162,2	1090,2	990,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**10.151**
Austria	77.671	2007	2599,3	2274,4	1990,1	1593,9	1394,7	1308,2	1189,0	1031,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**13.381**
Austria	79.411	2008	3119,2	2729,2	2388,1	2089,6	1673,6	1569,9	1426,8	1237,8	1054,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**17.289**
Austria	75.006	2009	3743,0	3275,1	2865,7	2507,5	2194,0	1883,9	1712,1	1485,3	1265,5	996,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**21.928**
Austria	76.944	2010	4231,6	3930,1	3438,8	3009,0	2632,9	2469,7	2054,6	1782,4	1518,6	1195,3	1021,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**27.285**
Austria	76.680	2011	5077,9	4443,1	4126,6	3610,8	3159,4	2963,6	2693,5	2138,9	1822,3	1434,4	1226,2	1018,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**33.715**
Austria	77.144	2012	6093,5	5331,7	4665,2	4332,9	3791,3	3556,4	3232,2	2804,0	2186,8	1721,2	1471,4	1222,0	1853,8	0,0	0,0	0,0	0,0	0,0	0,0	**42.262**
Austria	79.163	2013	7312,2	6398,0	5598,3	4898,5	4549,6	4267,7	3878,6	3364,8	2866,8	2065,5	1765,7	1466,4	2076,2	1902,3	0,0	0,0	0,0	0,0	0,0	**52.411**
Austria	81.532	2014	8909,6	7677,6	6717,9	5878,2	5143,4	5121,2	4654,4	4037,8	3440,2	2707,8	2118,8	1759,6	2325,4	2130,6	1959,2	0,0	0,0	0,0	0,0	**64.582**
Austria	95.424	2015	0,0	9354,9	8061,5	7053,8	6172,1	5789,6	5585,2	4845,3	4128,2	3249,3	2777,8	2111,6	2604,4	2386,2	2194,3	2293,0	0,0	0,0	0,0	**68.607**
Austria	106.731	2016	0,0	0,0	9822,7	8464,6	7406,5	6947,5	6314,2	5814,4	4953,9	3899,2	3333,3	2768,2	2916,9	2672,6	2457,6	2568,2	2564,7	0,0	0,0	**72.905**
Austria	109.191	2017	0,0	0,0	0,0	10313,8	8887,8	8337,1	7577,1	6573,3	5944,6	4679,1	4000,0	3321,9	3358,8	2993,3	2752,6	2876,4	2872,5	2938,7	0,0	**77.427**
Austria	119.242	2018	0,0	0,0	0,0	0,0	10829,5	10004,5	9092,5	7888,0	6720,6	5614,9	4800,0	3986,2	3829,1	3446,8	3082,9	3221,6	3217,2	3291,4	3594,3	**82.619**

Table 4: Waste of large household appliances throughout the years, calculation model

Based on the lifespan and the amount put on the market of large household appliances, this calculation model evaluates the amount of products that shall accrue every year. The denoted measuring unit is tons.

As large household appliances have a lifespan of up to 14 years it needs to be considered that only the number of products put on the market in the past will accrue at a certain time. Therefore, only an accurate statement can be drawn with the year 2014, since then the first lifecycle of the products is complete and 100 percent that were put on the market initially will be disposed, which means that after the year 2014 the amount accrued is accurate.

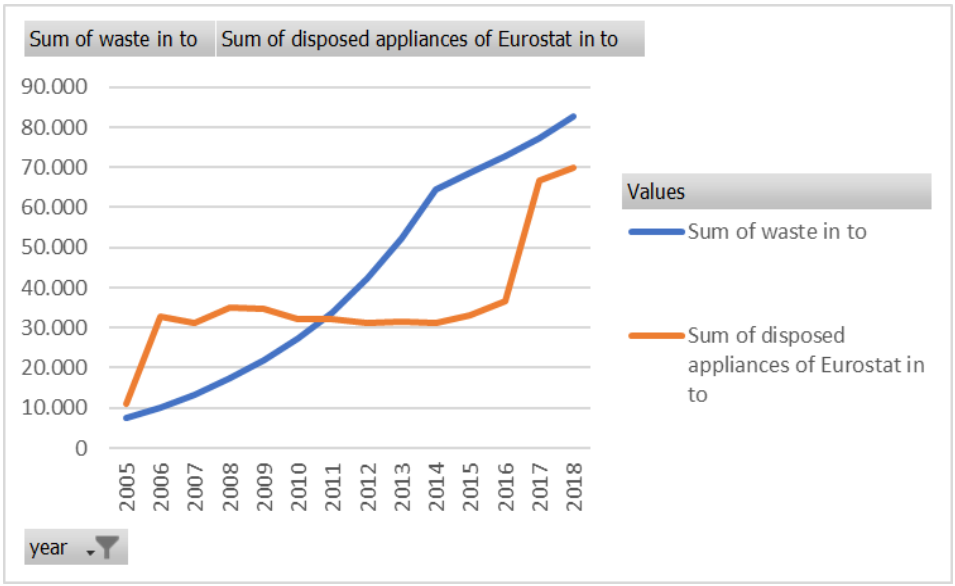


Figure 3: Comparison of waste of large household appliances throughout the years

Figure 3 shows the comparison of large household appliances that must accrue based on the developed calculation model (blue slope) and the appliances that are disposed within Austria (orange slope) based on the statistics published from Eurostat.
Only after the year 2014 a proper assessment can be drawn, due to the 14 years lifespan of large household appliances. After 14 years 100% of the products put on the market need to accrue as waste. Therefore, the data of waste before 2014 cannot not be considered as fully precise due to a lack of data of how many products are put on the market in the past. This is the reason the analysis (see Figure 6) shows a crease in the year 2014 and can only be held accountable between the years 2014 and 2018.

Table 5 shall give a more exact insight into the absolute amount of waste that is expected to accrue and the waste that is collected by Austria and statistically assembled by Eurostat. The difference shown as the grand total indicates that that the amount of collected waste is fewer that the waste that is expected to accrue. In fact, the absolute amount results in 128.862 tons more waste that shall have accumulated, from 2014 until 2018, based on the amount of large household appliances put on the market and their lifespan.

Year	Sum of waste in to (lifespan)	Sum of disposed appliances in to (Eurostat)
2014	64.582	31.199
2015	68.607	33.172
2016	72.905	36.497
2017	77.427	66.587
2018	82.619	69.823
Grand Total	**366.140**	**237.278**

Table 5: Absolute comparison of waste of large household appliances after 2014

5. Recycling of large household appliances

Waste of large household appliances falls under the directive of waste of electronic equipment. Especially waste of large household appliances is a major contributor to the collected waste of electrical and electronic waste in the European Union. With 52,7% it holds the biggest share of E-waste per appliance type in the EU. (*E-waste in the EU: facts and figures (infographic) | News | European Parliament*, 2020)

The yearly amount of E-waste generated in the European Union is rapidly growing and counts as one of the fastest growing waste streams. The European Union has set itself goals to tackle the problem and engage into a more sustainable production and consumption of electronic and electric equipment. Therefore, the European Union has introduced the WEEE Directive, which focuses on the improvement of a more sustainable production and consumption, an increase of resource efficiency as well as a contribution to a circular economy.
More specifically, the Directive of the EU puts focus on the following:

- Prevention of the initial creation of electrical and electric waste
- Engage the efficient use of resources through proper forms of recovery, re-use and recycling
- Improvement of performance of all parties involved in the cycle of EEE

(*Waste from Electrical and Electronic Equipment (WEEE)*, 2012)

The European Union has set minimum requirements for the member states to properly treat WEEE. Those requirements have not changed within the last 20 years. (*EU-Standards für E-Abfälle*, 2021)

Nine member states of the European Union (AT, ES, SK, DE, BE, FT, LU, IE, PT) have adopted their own national minimum requirements concerning the treatment of WEEE going beyond the Directive. In particular cases, these national provision's minimum requirements consist of elements of the CENELEC. CENELEC is a Committee of the European Union, that focuses on the Electrotechnical Standardization and it is one of the three big European standardization bodies.
The Austrian legislation, for example, foresees the treatment of "freezing and cooling household appliances" shall be executed in coordination with other standards. Generally

speaking, treatment requirements of electrical and electronic waste are carried out in the "Ordinance on Waste Treatment Obligations303". The owner of the waste is responsible for the proper fulfilment of the set requirements. This ordinance determines set requirements, which range goes far beyond the requirements of the European Directive of WEEE as well as fractions of WEEE. Nevertheless, requirements for the preparation for re-use of WEEE is only laid out for one WEEE category (products for temperature exchange equipment containing specific components). (Directorate-General for Environment (European Commission) *et al.*, 2021)

Sellers, manufacturers or distributors of electrical and electronic equipment, such as refrigerators or computers, are required by EU as well as national law to contribute to the orderly treatment and disposal of WEEE.
Those obligations include the following:

- Registration with authorities in each country where equipment is sold or distributed
- Regular submission of reports stating the quantity sold of electrical and electronic equipment.
- financing or organizing the treatment of products, including the collection, recycling and recovery.
- Setting up a take-back service for distributors such that customers are able to return WEEE without fees.
- For producers, to meet compliance with the Directive on the constraint of the usage of hazardous substances.
  (*Elektro- und Elektronik-Altgeräte – Pflichten der Hersteller und Erzeuger*, 2022)

6. Comparison of WEEE-Management in two EU countries

The last decades have been characterized with a significant increase in the development and consumption of electrical and electronic devices. With this increase, a rise in the amount of waste in this sector is inevitable. Due to the composition and complexity of electronic and electrical devices, it counts as one of the most complicated waste types to recycle. It contains possibly hazardous or toxic components that harm the environment as well as humankind. As it represents a big waste stream in the European Union, it needs to be collected with care and managed properly. (Pacesila *et al.*, 2016)

Austria and Romania were considered the two countries being compared in a European context. This decision was made due to the common targets of waste management and recycling of E-waste set out by the European Union. A comparison of the two countries shall highlight the different strategies the countries pursue while working towards the same goals.

6.1 Treatment of WEEE in Austria

Austria is considered a model of their waste policies in the EU, particularly recycling.
The Federal waste management system of Austria boarders the notional policy regarding the waste management. Companies holding over twenty employees need to submit waste management concepts to the government. Furthermore, Austria has created a waste management plan in 2011 which registers all waste treatment, processing and recycling facilities. (Collin, 2015)

Austria outlines and considers electric and electronic devices as such if:

- they are operated with electromagnetic fields or electric current.
- they produce, transmit or measure electromagnetic fields or electric currents.

The objectives of the national regulations concerning the waste of electrical or electronic equipment are set out as such:

- waste of electric and electronic equipment shall be avoided or prepared for reuse/recycling.
- at least 65 percent of products put on the market shall be collected separately.
- Restriction of the use of hazardous substances in electrical and electronic equipment.

The Austrian legislation set out specific laws for manufacturers as well as importers concerning the configuration and the composition of electric/electronic devices. Those obligations comprise, for example, the possibility of recycling throughout all devices or the limited usage of hazardous heavy metals.
Furthermore, the legislation set out “take-back obligations” of old electronic and electric devices for manufacturers, importers and final distributors. (*Elektroaltgeräte*, 2023)

According to the a study of 2020 of the Statistical Department of the European Union, Austria was, in 2017, with 50,1% under the top 5 performers when it came to the recycling rate of waste of electrical and electronic equipment. (*Elektroschrott in der EU: Zahlen und Fakten (Infografik) | Aktuelles | Europäisches Parlament*, 2020)

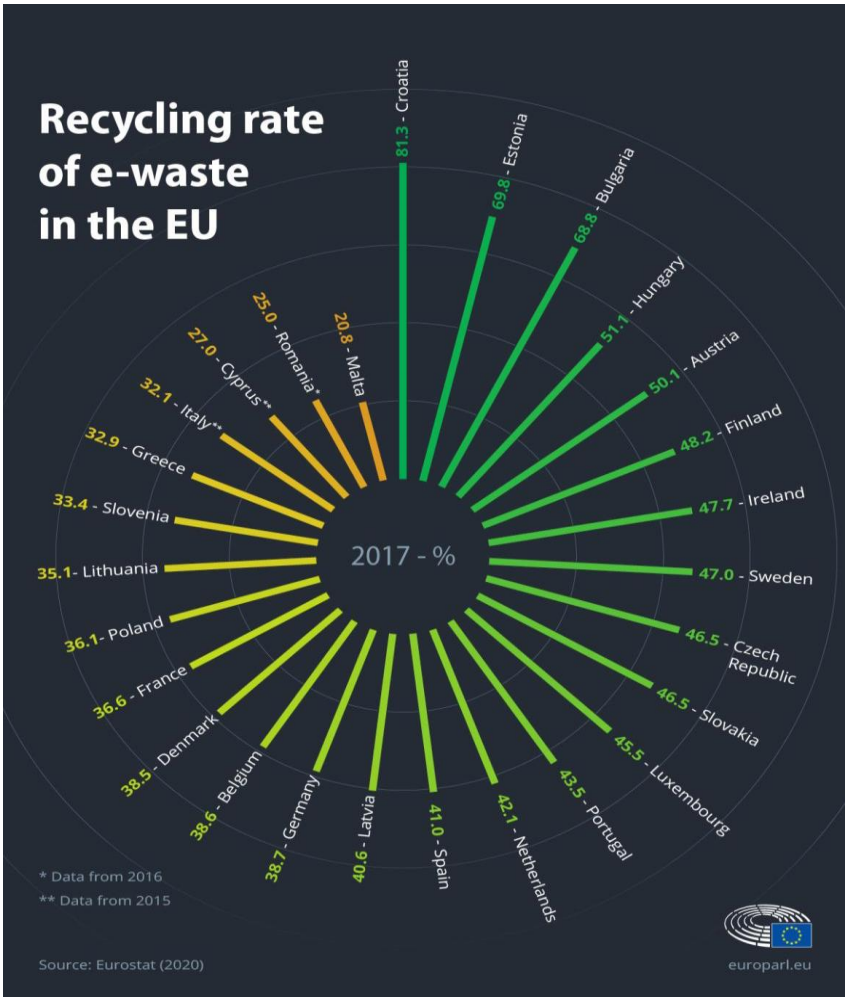


Figure 4: Recycling rate of E-waste in the EU, 2020

The Federal ministry of the environment in Austria has established a “repairing-sponsorship” for electric and electronic equipment. It was founded in April 2022 and focuses on private households as well as companies. A fund of 130 million euro are provided by the funding and development instrument “Next Generation EU” by the European Union until 2026. With this bonus, individuals can receive a subsidy of up to 50% of the repairing cost but with a limit of € 200. For receiving a cost estimation of participating partner companies the bonus is limited to € 30. This bonus is not only valid for large household appliances but all household appliances of any size. (*Für Privatpersonen | Reparaturbonus*, 2022)

The goal of this initiative is to emphasize the thought of a circular economy and reduce the necessity of resources to protect the environment. Other benefits targeted with this subsidy is to decrease the disposal of waste and increase the usage of easy fixable appliances, the preservation of know-how, craftsmanship and labor power in the region as well as strengthening the local repairing scene. (*Reparaturbonus*, 2022)

6.2Treatment of WEEE in Romania

After becoming a candidate and shortly after a member of the EU, Romania has developed a WEEE management in a rather short period of time. Romania adopted the regulations of the European Union into the national regulations. Before that, the management system of E-waste was very unclear and therefore waste of electrical and electronic appliances was mostly found, with other waste types, in landfills. Nevertheless, inhabitants in Romania owned electrical and electronic equipment with a lifetime almost double compared to other countries of the European Union. Reasons of the prolonged usage related to the general limitations of ownership of EEE consist of a longer usage due to lower incomes as well as difficulties to provide collection infrastructure in rural areas.
In 2010, Romania developed objectives to establish WEEE management:

- General prevention of WEEE. Creation of forms of recovery such as reuse and recycling in order to reduce the quantity of waste.
- Improvement of the overall performance of all operators of the lifecycle of electrical and electronic equipment (consumers, producers and distributors).

(Torretta *et al.*, 2013)

Although the continuous implementation of regulation of the European Union, Romania is still facing issues regarding a proper collection of its E-waste.
Sales of EEE have increased over the last years due to constant improvement of living standards, technological progress as well as access to loans for consumers. Romanian households amount of EEE and their average usage is higher compared to other member states of the European Union and it is expected that the amount of Waste of those products will increase steadily.
The Romanian collection system for waste of electrical and electronic equipment has only been implemented after its entry in the EU. Due to a lack of appropriate infrastructure, it is ranked under the worst performers when it comes to WEEE collection in the European Union. Figure 4 shows Romania ranked second to last back in 2017 in comparison to all member states of the European Union.
According to a study conducted by Ecotic and GBD Research (2016), the biggest barrier to the proper collection of WEEE is the lack of facilities for separate collection, followed by poorly communicated information of the location of the collection points. (Pacesila *et al.*, 2016)
Furthermore, nearly half of the population of Romania lives in rural areas, which often results in a badly equipped population. The average usage for large household appliances of member states of the EU lies between 8-10 years, whereas the Romanian average lies between 13-17 years. Inhabitants of rural areas even use household appliances over the recommended lifespan by the manufacturer (sometimes even decades).
Therefore, due to the very low renewal rate in these areas, it is rather difficult to organize even the basic processes of waste management. (Pacesila *et al.*, 2016)

Romania has established several channels nationwide in order to create awareness in the population on how important E-waste collection is, such that the government can meet their objectives. Those channels consist of the following:

- Establishment of a “collection day”: Improvement of citizens’ knowledge of E-waste by setting a day where WEEE can be collected from households.
- Establishment of a “one-to-one” / “buy-back” system: The electronic product bought must be similar to the electronic product returned. Discounts are offered if customers bought a new appliance from the same product line.
- Establishment of collection centers: Possibility of discarding WEEE without fees at municipal collection centers. (Pacesila *et al.*, 2016)

7. Conclusion and limitation

E-waste Management plays an important role in Europe. Waste of electrical and electronic equipment is an ever-growing waste stream in the European Union and counts as one of the fastest growing waste streams globally. The EU enforces laws aiming at a more sustainable consumption and production of those appliances. Nevertheless, waste still accrues and member states of the EU are responsible for complying with them.

When it comes to E-Waste management processes and recycling a few things need to be considered. The recycling and waste management process in Austria counts as one of the best ones in the European Union. Even though Austria counts as one of the pioneers when it comes to recycling of EEE, the data on this needs to be questioned. A recycling rate of any kind only accumulates of properly disposed items. Hence, appliances not orderly disposed will not appear in the recycling statistics. Furthermore, statistics show the amount that is collected by the state, which is no evidence about how much waste incurred. Therefore, a calculation model was created to show how many products are expected to accrue yearly. The calculation model carried out in this master thesis indicates that, based on the amount of large household appliances put on the market as well as their lifespan, more waste is expected to accrue than it is collected.
Therefore, while Austria is considered one of the countries with the best collection and recycling rates throughout the European Union, there is a big estimated number of unreported waste of large household appliances.

Even though Austria and Romania are both members of the European Union and work towards the same goals their waste management system of E-waste differs. The fact that Romania has entered the EU later challenged the country to establish those laws in a short period of time. Due to cultural and social differences and lack of understanding Romania struggled with communicating the importance of WEEE to its population.

The country enforced three lines of actions regarding the establishment of WEEE: The continuous development of the infrastructure of collecting, recycling and recovering E-waste; educating its population regarding the importance of collection and recycling of WEEE; establishing and improving institutional and legal initiatives concerning the correct regulation of this area. (Pacesila *et al.*, 2016)

Austria, on the other hand, has had several years to establish its supply chain regarding waste management due to its earlier entry in the EU. Furthermore, Austria is considered a rather

wealthy country in the EU and therefore, has the necessary resources to establish certain frameworks. Studies have shown that Romania struggles especially with communicating possibilities of waste management to the rural areas and therefore has difficulties establishing sustainable waste management frameworks.
Since owners of electrical and electronic appliances in the EU are responsible for properly disposing them, citizens even more need to understand and respect their role in the WEEE process.

Since Eurostat does not offer data of a very long period, assumptions needed to be drawn in order to draw valid conclusions. This master thesis shall provide a basis for further research to question the current data provided by the European Union. Only if a big set of past data is provided, proper statements can be drawn for the last decade, which results in a limitation of this master thesis. However, it shall help understand that the recycling rate itself has a very low explanatory power due to the big number of unreported cases that evidently exist in Austria. This shows that even in well developed countries there is a need to catch up and to constantly improve their supply chain management.
Furthermore, it provides the basis for researching possible explanation of what happens with the waste that accrues but does not get disposed in Austria as well as how the substitution program of Austria influences the current waste situation and if this program could be beneficial for other member states of the European Union.

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