Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management **7** (2020) (2) 137-151

24th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 3th-6th November, 2020, Rimini, Italy

TECHNIQUES FOR THE VALORIZATION OF GLASS ON TELEVISION SCREENS IN THE MANAGEMENT OF WEEE*

Gioele Giaquinta[1], Rocco Liardo[1], Andrea Cannavo[1], Agata Matarazzo[1], Vincenzo Giuffrida[2]**

[1]University of Catania Department of Economics and Business, 55 Corso Italia, 95129 Catania, Italy
[2]FG Recycling System ltd, Strada Comunale San Todaro 20, 95032 Belpasso (Catania), Italy

Abstract

The linear economy model is no longer applicable, the transaction to a circular model is necessary to ensure the use of the entire value of natural resources for both current and future generations. WEEE is the waste deriving from electrical and electronic equipment, regulated by legislative decree 151/2005 and next 49/14. The bad management of these wastes generates an environmental impact that represents a problem for the environment. We need to find a quick and effective solution by making the most of the new technologies that allow us to recover an ever-greater part of the components, which can be used as secondary raw materials. The objective of this paper is to investigate the technological innovations in the management of glass deriving from cathode ray tube televisions proposing a correct management of these materials at the end of their life. We present an application case study in the company FG Recycling System ltd located in Belpasso which deals with the management of waste from both dangerous and non-hazardous electrical and electronic equipment. Through a mass balance we will analyze the advantages deriving from the correct management of this glass which concern the lower environmental impact, the reuse of secondary raw materials, the reduction of the disposal costs.

Keywords: cathode ray tube, circular economy, environmental impact reduction, glass recycling, WEEE,

* Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: rocco.liardo@gmail.com

1. Introduction

Every year, In Europe, 6.5 million tons of waste from electrical and electronic equipment are produced and represent about 8% of all municipal waste produced, with an estimated growth of 16-28% every five years. The current economic system is based on a linear approach, in fact, companies buy raw materials, transform them and sell the finished products that are bought and used by consumers until they become waste for disposal (Di Bella et al., 2019).

The European Union with the Europe 2020 strategy is set as an objective the efficient use of resources and the only way to achieve it is the change of the economic system, i.e. the transition to a circular economy model in which waste is reused to exploit their value. Starting from the definition of this model and of the regulations, the concept of secondary raw material will be analysed in order to move on to the application techniques of the circular economy and reach the advantages obtainable with the application of the circular economy, in the dual perspective of environmental and economic at the same time, lastly, conclusions will be drawn.

According to the definition of the Ellen MacArthur Foundation, the circular economy represents "a type of economy that can regenerate itself" (The Ellen MacArthur Foundation, 2013). The circular economy is therefore an economic system planned to reuse materials in subsequent production cycles, minimizing the waste through the practice of the "three Rs": reuse of materials, recycling and energy recovery (Yuan et al., 2006).

The concept of sustainability was born from an ecological, economic but also social point of view (Matarazzo et al., 2018) It is declined in two forms: the weak one in which the replacement of natural capital with other types other than this is allowed, for example human or physical capital, therefore, the exhaustion of natural capital is compensated through savings in other types of capital. The strong form of sustainability does not allow the replacement of natural capital with other types (Andersen, 2007)

Production is designed from a circular point of view, i.e. the resources are initially obtained from the environment, and that the waste, produced by their use, itself becomes resources that can be used through recycling, giving life to a sustainable production process. (Matarazzo and Baglio, 2018)

The principles on which the circular economy is based are three (Arfò et al., 2019):

- To preserve and improve natural capital, that is to use natural resources only where necessary and in other cases to rely on renewable resources that are not subject to depletion.
- Optimization of resource returns through the circulation of products, components and materials, obtaining maximum utility from them and exploiting the entire life cycle.
- Increase the effectiveness of the system by revealing and deleting negative externalities.

According to Global Footprint Network, the planet earth needs a year and a half to produce and absorb what is consumed as raw material and eliminated as waste over the course of a year. Over the last decade, the value has increased, passing 1.5 planets Earth to 1.75 (www.footprintnetwork.org).

July 29, 2019 was the day when humanity completely consumed the resources produced by the planet throughout 2019; this day is known as "Earth overshoot day" or "day of ecological debt". Italy consumed everything it had already produced on May 15th.

In 2020 it is estimated that the ecological debt day will be later, due to the Covid-19 pandemic that has affected humanity, the efforts to contain it and the consequent economic slowdown have reduced humanity's footprint.

To reduce the impact of mankind on the planet, a series of directives have been issued over the last decade: in 2010 the European Commission presented the new Europe 2020

strategy, developed with the aim of facilitating the exit from the economic crisis and outlining a development model in order to adequately respond to the challenges of the 2010-2020 decade.

In 2014, the European Commission, through communications EC COM 397 (2014) and EC COM 398 (2014), outlined its position in favour of a strategy that aims at an efficient use of resources, trying to remedy market gaps and obstacles to reuse.

In 2018, 4 directives were born that modify the previous 6 in terms of waste, packaging, landfills, WEEE, end-of-life vehicles and batteries (Ingrao et al., 2019).

They are detailed below:

- DIRECTIVE 2018/849/EC: concerns: end of life vehicles, WEEE, batteries and accumulators, it amends three previous directives (European Directive 849, 2018);
- DIRECTIVE 2018/850/EC aims to prevent and reduce as much as possible the negative impact of landfills on surface water, groundwater, soil, atmosphere and human health, by introducing strict technical requirements (European Directive 850, 2018);
- DIRECTIVE 2018/851/EC: aims to help the European Union get closer to a recycling society, trying to avoid the production of waste and to use waste as a resource (European Directive 851, 2018);
- DIRECTIVE 2018/852/EC: this directive amends directive 1994/62/EC on packaging and packaging waste. In particular, it aims to contribute to: improving the quality of the environment; protect human health, resources; ensure the functioning of the internal market and the restrictions of competition within the Union (European Directive 852, 2018);

In the last two years, through communications, efforts have been made to implement an action plan for an increasingly green economy, in particular: communication EC COM 640 (2019) is known as the "Green Deal", it defines a plan of action to make the EU economy sustainable, transforming climate and environmental challenges into opportunities in all policy areas. This is a new growth strategy to make Europe cleaner, safer and healthier. On 11 March 2020, a new action plan for the circular economy "for a cleaner and more competitive Europe" is proposed through the communication EC COM 98 (2020) of the European Commission (Matarazzo, 2018).

WEEE, and in particular televisions, once discarded from homes end up at the landfill sites and then they are sent for treatment to special treatment centers. With proper management, approximately 85% of the components can be exploited.

The percentage of WEEE in relation to the quantity of waste produced is very high, a growth of 5% is estimated every year, but this value is expected to grow more and more. Therefore, professional commitment and correct management methodology are required in order to avoid unpleasant damage to the environment and human health. The company FG Srl, located in the municipality of Belpasso (CT) deals with the collection and management of WEEE, committing itself to ensuring a correct management of this waste, benefiting both the environment and the economy, drawing itself economic benefits from the their correct reuse. Through a mass balance, the economic and environmental convenience of the internal management of new generation televisions will be assessed.

2. Case study: FG ltd

FG ltd is a small-medium business that owes its name to the entrepreneur Giovanni Failla, a very ambitious man who is managed to create the current company, one of the best known in Sicily and which stands out for its professionalism and attention to detail, in interests of the environment and human health. The company is constantly updated, tries to adopt innovative techniques, improvements in current processes, aimed at not only reducing the environmental impact, but also at satisfying customer needs. The company is located in

Belpasso (CT) at the San Todaro Municipal Road; the position is not accidental, but has been chosen respecting expected environmental tolerance requirements. The company, in which more than 50 employees currently work, deals with the disposal of waste electrical and electronic equipment, both dangerous and not; moreover, with the skills acquired over the years it is specialized in their treatment and recovery at the end of their life. Its origins date back to 1974, the year in which FG opened the first plant that is it only dealt with the treatment of refrigerators which still represent 80% of their core business today. In the premises where it is currently located, it has an area of 20,000 m^2 of which over 6,000 m^2 covered (https://www.fgambiente.com). The vision of FG is based on continuous improvement and the desire to grow while respecting the planet, the company, in fact, wants to specialize and optimize plant engineering and, therefore, WEEE waste treatment operations by creating an increasingly dense network between the main actors such as: public entities, collective systems and private companies. All this has allowed the company to move forward until it becomes today a flagship for Sicilian entrepreneurs. The company specializes in the storage of hazardous and non-hazardous materials, it helps in fact, the main suppliers are the public to dispose of the main types of waste produced in the context of professional activities administration and companies in particular offices, industries, craftsmen, service centers and mechanical workshops. It also offers a service environmental consultancy, and specializes in the remediation of contaminated areas and in the safety of areas polluted by asbestos and eternity. FG operates throughout the Sicilian territory through the collection of waste which takes place through vehicles approved for the transport of hazardous waste according to ADR regulations (2011). THE waste, once it has flown into the company, is subjected to a treatment process and subsequently will be sent to customers of the company, that is, companies with production processes that exploit these materials in the form of secondary raw materials. The company, as well waste treatment and disposal, collaborates with various consortia including Ecodom, Remedia, Ecolight, Ecoped, aiming to environmental protection.

The WEEE that the company treats today are:

- Category R1: this category mainly includes refrigerators and freezers; this represents for the company the area thicker in terms of quantity. This category of waste can be defined as hazardous if it is not treated with the due precautions given the presence of CFCs and other types of gas.
- Category R2: this category includes the Great Whites, including: washing machines, dishwashers, microwave ovens, hobs etc. The management of this waste presents some similarities with the previous one; the only difference is due to the fact that processes are more simplified due to the resource they will have to work with.
- Category R3: which includes TVs and monitors. This category of waste is managed manually, the waste has some dangerous substances inside them, in particular, lead inside cathode ray tube televisions.
- Category R4: which includes small appliances, consumer electronics, ITC and more, including lighting equipment and all the others outside the previously mentioned groupings.

The company's production process is aimed at treating WEEE, it involves several stages:

- Acceptance, in this phase the weighing of the means of transport takes place and the value net of the tare is noted in a loading and unloading register;
- Organizational verification and sorting of waste in the areas where the treatment will subsequently take place;
- Safety through the elimination of materials that are hazardous to the environment and human health.
- Disassembly e separation of the various components.

- Crushing of the components already separated and destined for recovery or, ultimately, for disposal.

The company has acquired and maintains the following certifications:

- ISO 9001 is an international standard relating to quality management.
- ISO 14001 is the international standard for designing and implementing an environmental management system;

3. Materials and method

In today's society everyone has at least one electronic device, and given the development of technological progress, the numbers will tend to increase. In Europe 6.5 million tons of waste electrical and electronic equipment are produced every year they represent about 8% of all municipal waste produced, with an estimated growth of 16-28% every five years (Dalrymple et al., 2007). This growth represents an advantage for companies that increase their production more and more but if one is not carried out correct management of these assets, the resulting damage will be unspeakable, especially if we focus on the end of the cycle of life of these goods we can see that they are waste, and that their incorrect management could cause potential damage to the environment and human health (Goosey, 2014). These generated wastes are classified as WEEE and in particular, it is estimated that each inhabitant produces 4.89 kg each year, but the trend will tend to grow if an adequate management system is not developed (Widmer et al., 2005). These wastes are distinguished from common ones because they contain the presence of dangerous substances therefore if they are not managed correctly, in terms of safety or remediation, disassembly of sub-assemblies and separation of materials, and finally mechanical processing for the recovery of materials, could represent a risk (Tsydenova and Bengtsson, 2011). The risks are different depending on the type and quantity of hazardous chemicals contained in WEEE. The main ones are essentially the environmental ones linked to the contamination of the soil and aquifers and those relating to human health deriving in particular from the presence of heavy metals. You can look at the issue from two points of view: that of consumers and that of businesses. WEEE but more generally waste is associated with consumption, It is necessary that man, who today lives in a consumer society, increases his commitment as a consumer. It becomes, therefore, really complex to understand that the only possible solution to the waste emergency lies in consuming less or, more correctly, in reorganize production assets in such a way as to make possible different and more sustainable forms of consumption (Kwak et al., 2011). This waste also represents a problem for companies that have to bear the burden of disposal, sometimes not so low, even if some more proactive companies are exploiting WEEE for the recovery of some components that may be reused, the so-called secondary raw materials, this greatly enhances the waste, making it become an opportunity from a problem (Cooper, 2004). However, it is only right to underline that despite this commitment of the companies, a brake is represented from technological obsolescence which is configured as the loss of value of an asset caused by technological progress and therefore aims precisely to encourage the production of these goods and therefore to increase waste. The legislation on WEEE is partly imposed by the European Union through specific directives that can be implemented directly as such if there is adequate clarity and particularity, or, it can be implemented by decrees that specify it better adapting it to the geographical context.

Below they are illustrated the main reference regulations:

- EUROPEAN DIRECTIVE 2002/95/EC: aimed at removing states from the use of dangerous substances in the phase of production of EEE to ensure the protection of human health (European Directive 95, 2002).

- EUROPEAN DIRECTIVE 2002/96/EC: the first measures to prevent excess production are generally dictated of WEEE and for a correct management of the end of life in terms of recycling (European Directive 96, 2002).
- LEGISLATIVE DECREE 151 (2005): was created to implement directives 2002/95/EC and 2002/96/EC. Represents the basics for the correct management of WEEE, in particular of waste deriving from: large and small appliances, equipment IT and telecommunications, etc. (Legislative Decree 151, 2005).
- EUROPEAN DIRECTIVE 2006/12/EC: the states agree to ban the abandonment of waste and undertake to promote recycling; greater emphasis on cooperation between states to create an integrated network to aid disposal autonomous of each individual state (European Directive 12, 2006).
- LEGISLATIVE DECREE 185/2007: establishes the management bodies of the WEEE system such as the National Register of subjects obliged to finance the WEEE management systems, the WEEE coordination center and the Committee of guidance on the management of WEEE (Legislative Decree 185, 2007).
- EUROPEAN DIRECTIVE 2008/98/EC: introduces the waste hierarchy and reaffirms the principle according to which the polluter pays and that of extended producer responsibility, i.e. the obligation to manage the final phase both in terms of withdrawal from the customer and in terms of assuming the economic burden (European Directive 98, 2008).
- EUROPEAN DIRECTIVE 2012/19/EC: it replaces directive 2002/9/EC, developing a new classification of WEEE. It underlines the need for cooperation between producers and WEEE treatment centers to allow EEE buyers to return the old ones free of charge (European Directive 19, 2012).
- LEGISLATIVE DECREE 49/2014: currently represents the cornerstone of the WEEE discipline, it replaces the 151 of 2005, of which only some technical regulations remain valid. The decree was created to implement the Directive 2012/19/EC (Legislative Decree 49, 2014).

WEEE have been defined by Legislative Decree n. 151/2005 and divided into two macro-categories, they are: Domestic WEEE are those waste of electrical and electronic equipment from both real households and commercial, industrial origin, institutional and other types similar in nature and quantity to those originating from households. These merge into a Municipal or private collection center and subsequently transported to authorized treatment plants. Professional WEEE are those wastes of non-domestic electrical and electronic equipment and therefore deriving from economic or administrative activities (Legislative Decree 151, 2005). Unlike the former, these are delivered directly to the treatment plants authorized. The WEEE had been divided into 10 groups, as present in Annex IA of Directive 2002/96/EC and in Italy transposed as Legislative Decree 151/2005:

1. Large household appliances;
2. Small appliances;
3. IT and telecommunications equipment;
4. Consumer equipment;
5. Lighting equipment;
6. Electrical and electronic tools (except tools large-sized fixed industrial plants);
7. Toys and equipment for sport and leisure;
8. Medical devices (ad except for all implanted and infected products);
9. Monitoring and control tools;
10. Automatic dispensers (Decree Legislative 151, 2005).

This division remained in force until 14.08.2018, the date on which it was replaced by Annex III of Legislative Decree 49/2014 which led to a reduction of the categories from ten to six, three of which based on a dimensional criterion, but to a contextual extension of the

scope of application (Legislative Decree 49, 2014). Nowadays for easier understanding and to optimize logistics, WEEE is commonly divided into five groups, reorganizing the categories in the annex IB of Legislative Decree 151/2005:

- Grouping R1 Cold and climate: all appliances with a cooling function fall into this grouping.
- Grouping R2 Large whites: this grouping includes washing machines, dishwashers and similar appliances.
- Grouping R3 TV and Monitor grouping.
- Grouping R4 small household appliances, consumer electronics, lighting equipment, pressure equipment and more: all categories not mentioned in the other groupings referred to in this annex also fall into this grouping.
- Grouping R5 Light sources.

In the WEEE sector, innovation is essential because it is necessary to create the basis for the reuse of components that are still functional despite the fact that the EEE is no longer functional, but at the same time to avoid the accumulation of old WEEE which, if left like this, creates degradation and damage to the environment. Many techniques are no longer manual but automated thanks to the use of robots, the main ones being the shredding and separation. The shredders are distinguished according to the number of trees present; the double shaft shredders are the machines for the volumetric reduction phase, they thus prepare the materials for the subsequent phases, which will be carried out with three and four trees. Initially this technique was applied only to large WEEE but was subsequently extended to those of small size (Peng et al., 2004). The separation processes are divided into: magnetic separation, based separation on electrical conductivity and density-based separation. Magnetic separation is widely used for metal recovery ferromagnetic from non-ferrous metals. Over the past decade, advances in design have led to the creation of the high intensity magnetic separators to allow to separate the copper alloys from the waste matrix (Gungor and Gupta, 1998).

4. Result and discussion

Correct management of WEEE is essential to avoid damage to the environment and human health, therefore there must be correct collection by consumers, safety measures to avoid risks, treatment appropriate to the category and finally it is necessary to apply an end-of-life strategy suitable for the WEEE in question (Cui and Forssberg, 2003).

Waste collection is the process that begins with the consumer who gives his WEEE free of charge at the designated places, continues with the purchase of a new one (one vs one) or, if small, without the purchase of one by the equivalent function (one vs zero).

The WEEE initially flow to the collection centres and are subsequently transported to the appropriate facilities for proper treatment; Unlike domestic WEEE, professional WEEE is collected directly from companies or institutions to be then transported directly to treatment plants. The collection of WEEE has seen a percentage increase in the last 10 years, in particular between 2017 and 2018 there was an increase of 5%; moreover it must be emphasized that the R3 category has a decreasing trend as already estimated by the experts which is due to the technological change of the devices in that category.

After collection, we proceed with the safety and treatment of WEEE, in particular there is: an initial dismantling, then there is the safety and finally recovery of the parts still reusable in order to extend the life cycle of the product. It must be emphasized that safety is essential because WEEE can contain dangerous substances inside, so any type of risk related to both the environment and human health must be eliminated. It is essential that the transport is carried out safely to avoid the dispersion of these substances in the air and that

the treatment centre is equipped to receive these devices and treat them as required by law. (Bhuie et al., 2004)

The various processing steps for each group are listed below:

- The R1 grouping includes equipment characterized by the presence of a refrigerant circuit containing gases harmful to the atmosphere, therefore it requires specific processes for remediation. All the previous phases such as: collection, transport and storage must take place in such a way as to keep the equipment intact, thus avoiding the spreading of dangerous substances. The treatment process is divided into the following stages: disassembly of the components, reclamation of the refrigerant circuit with the suction of oil and gas, and finally disassembly of the compressors.
- Group R2 brings together large appliances that do not contain a refrigerant circuit; therefore, the danger is less. This equipment is subjected to manual disassembly and safety.
- The treatment of the R3 group of waste is divided into two different categories: treatment of monitors and televisions with cathode ray tubes and treatment of equipment with flat screen, since they have very different characteristics. The screens must be kept intact to avoid the dispersion of contaminants.
- The R4 grouping includes a large variety of equipment that is collected and delivered to the facility and then mixed together. The treatment cycle of this group is divided into the following phases: selection by type of equipment, removal of hazardous components, manual disassembly of materials that can be used, shredding and separation of materials.
- Group R5 includes waste from lighting equipment, it is possible to recover considerable quantities of materials equal to about 90% of the product, thus thinking of their subsequent reintroduction into the market. In particular, think of glass which is currently the material with the greatest commercial potential, as it can be reused in various sectors.

The end of life of a WEEE managed in a sustainable way is represented by one or more of the following alternatives:

- reuse: which consists in the recovery and sale of used products as originally designed.
- maintenance: it is aimed at lengthening the use phase of a product through repair or maintenance.
- regeneration: is the removal of specific parts of the waste product for further reuse in new products.
- recycling: is the recovery and reprocessing of the materials contained in the products and used in order to replace the materials in the production of new goods.
- disposal: consisting of incineration processes with or without energy recovery or landfill.

The reuse of equipment after a functional test is an option provided for in the WEEE legislation but there is no legislation on equipment returned to the market, so all the phases are carried out and it is difficult to re-enter the recoverable components on the market (Rose et al., 1999)

A particular treatment must be carried out for the R3 grouping, in which a differentiation must be made between cathode ray tube televisions and flat screen televisions, in fact, televisions have undergone an evolution over the years, the old cathode tube televisions have been replaced at the end of the 90s, thanks to technological progress, by the flat screen. These aren't longer bulky televisions, with a high weight and volume, but rather thin televisions in terms of thickness and more attentive to modern design.

The novelty is also in the interior of the TV which is no longer made up of the cathode ray tube, but of liquid crystals (LCD) which allows light to pass through the individual cells behind the screen to create an image, it was, therefore, it is possible to reduce

the thickness of televisions. In recent years the LCD has been replaced by the LED which stands for "light emitting diode". This new technology works like the LCD, but instead of the numerous lamps positioned behind the screen there is a large collection of small LEDs. In these televisions, unlike cathode ray tubes, the recovery of materials is easier thanks to the low percentage of dangerous substances inside the screens. In many televisions the glass is replaced directly by a plexiglass material that has a high density and transparency, the electronic boards are similar to those computers, therefore, the only components are the LEDs, whose danger is very low.

From Fig. 1 it is clear that for all waste categories there is an increase in terms of weight, for category R3 there is a reversal of the trend precisely because the volume and weight of new generation televisions is less than about one third compared to CRTs. The company expected a reduction in terms of weight already in the last three years but this has not yet happened because the new generation televisions are still present in homes, so it is thought that this decrease in weight will certainly occur in the coming years.

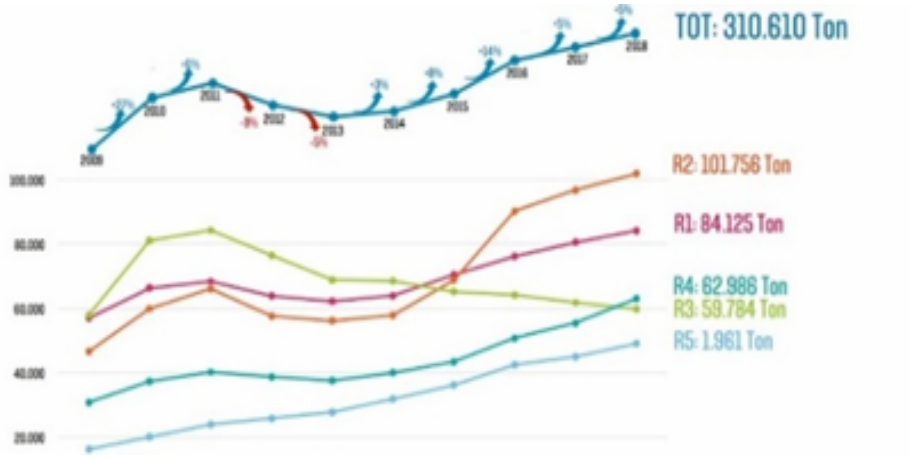

Fig. 1. Collection of WEEE 2018

Currently given the low percentages of incoming LCD televisions, the company in the R3 department manually manages only the CRTs, and not the new generations of televisions, but in recent years seeing an increase in the percentages of the latter and given its proactivity, the FG company also wants to specialize in the management of new generations of televisions, in particular LCDs. The U-turn will bring many benefits to the company resulting from the high percentages of materials that can be enhanced.

Through a mass balance, the advantages of internalising the production process of new generation televisions will be evaluated to avoid shipping them to other factories, which is currently very expensive for the company. In fact, by evaluating the investment and the economic and environmental advantage, it may request accreditation in the coming months.

The analysis consisted of several phases: initially five televisions were placed on the scale to carry out the input weighing, obtaining a weight of 51 kg. Subsequently, manual disassembly was carried out at the end of which the components were separated (Fig. 2), in particular, they are: Iron; Plastic; Electronic boards; Electric cables; Waste 191212; Glass.

Finally, we proceeded with the final weighing of the individual components, a process that was carried out several times to ensure that no mistakes were made and the results are presented in Table 1.

The mass balance shows that the incoming flow is equal to the outgoing flow. In particular, the components that the company would be able to exploit and the relative prices, which are purely indicative and strongly subject to fluctuations in the raw materials market (Table 2), are highlighted below:

- Iron is a very heavy and quite profitable component, considering that the company would be able to resell it in the form of secondary raw material at a price of € 150.00 per ton.
- Plastic, which occupies the second place in terms of weighing, is characterized by low weight and high volume, for this reason the company could proceed with a shredding operation. The company would be able to resell it at a price of € 50.00 per ton.
- Although electronic boards occupy a central position in terms of weighing, they are the most profitable component for the company, in fact the price at which they would be sold is € 1800.00 per ton.

Electric cables represent a very low percentage but can be resold on the market at a price of € 1000.00 per ton.

Fig. 2. Separation of components

Table 1. Mass balance

CER code	***Component***	***Weight in kg***	***%***
191202	IRON	22.30	43.72
191204	PLASTIC	15.00	29.41
191205	GLASS	6.00	11.76
160216	ELECTRONIC BOARDS	5.00	9.80
170411	ELECTRIC CABLES	1.00	1.96
191212	WASTE	1.00	1.96
200121	NEON	0.70	1.37
	Total	**51.00**	**100.00**

Table 2. Prospectus of potential revenues

CER Code	***Component***	***Weight in T (10^{-3})***	***Unit sales revenue in €***	***Total sales revenue in €***
191202	IRON	22.30	150.00	3.35
191204	PLASTIC	15.00	50.00	0.75
160216	ELECTRONIC BOARDS	5.00	1800.00	9.00
170411	ELECTRIC CABLES	1.00	1000.00	1.00
	Total			**14.10**

The components that the company is unable to exploit and which will therefore be destined for disposal are the following:

- The glass panel that can be shredded, but currently the company would not be able to enhance it, therefore it represents a cost of € 90.00 per ton.
- Waste 191212 the company would not be able to reuse it and would end up in landfills, with a disposal cost of € 120.00 per ton.
- Neon is a dangerous material due to the presence of mercury and should be managed by a centre that has the authorization for this hazardous waste, the company would incur a cost of € 100.00 per ton (Table 3).

Currently, the company incurs a cost of € 100.00 per ton for the treatment of this waste in authorized factories. These are essentially disposal costs as well as logistical and transport costs. If the company internalized and managed this waste itself, the previously mentioned costs would vanish. It should not incur any equipment costs or installation costs because it can very well exploit the area where the CRTs are managed. Table 4 shows the current prospects that show a loss due to the absence of revenues, and the future prospects if the company decides to implement the investment and then internalize the LCD production process, which would bring the company a profit. The company, although authorized to manage this waste, has not requested accreditation because it is still in an experimental phase, but within the current year it plans to do so, in order to start managing this waste internally in 2021.

With the granting of the authorization by the Region of Sicily, the FG will be able to respond to the growing percentage of waste deriving from new generation televisions that are currently in operation by already proactively engaging in future respect for the environment. By internalizing this phase of the production process, the company will derive economic advantages related to the reduction of costs given the production of raw materials directly in the plant, without the need to rely on others for the same process. For a proactive company that is attentive to environmental issues such as FG it is strictly necessary that an investment has a return also in environmental terms, this will lead to the reduction of emissions deriving from transport by land essentially: Sulfuric dioxide (SO_2), Nitrogen oxides (NOx), Nitrogen Monoxide (CO), Carbon Dioxide (CO_2), Fine dust such as $PM_{2.5}$ and PM_{10}; thus leading to a improvement in the atmosphere.

Table 3. Prospectus of potential costs

CER Code	***Component***	***Weight in T (10^{-3})***	***Unit cost of sale in €***	***Total cost of sale in €***
191205	GLASS	6.00	90.00	0.54
191212	WASTE	1.00	120.00	0.12
200121	NEON	0.70	100.00	0.07
	Total			**0.73**

Table 4. Prospectus of current and potential profit

Current		***Potential***	
Voice	***Value in €***	***Voice***	***Value in €***
Revenues	---	Revenues	14.10
Costs	5.10	Costs	0.73
Profit	**-5.10**	**Profit**	**13.37**

6. Conclusions

The WEEE annual report shows that collection is growing, the resulting advantages are of a dual nature: environmental and cheap. From an environmental point of view, the damage from improper management affects both the environment and man, due to numerous dangerous substances present inside the various devices, therefore a safety measure is needed to avoid that there is a dispersion of these substances. You cannot see the environment far from man and adopt opportunistic behaviors, you have to inform and let everyone know that the service offered to citizens is free and that they already bear the burden for future management.

From an economic point of view, on the one hand it can be objected that it is difficult but also burdensome to carry out a correct one management of WEEE, but thanks to the extended responsibility of the producer, the cost of management at the end of life is already distributed at the moment of the purchase on each device, and therefore on each consumer, moreover, as seen above, the management techniques are always updated and at the forefront with technological innovation. The resulting advantage does not only concern the cost and the environment but also the company that benefits from its competitors in terms of: cost: there is a reduction in costs because they can implement recovery and reuse strategies; quality: the goods and services offered appear qualitatively better; innovation: the company can allocate those financial resources saved in research and development activities; corporate image: consumers they will tend to choose our products over those of competitors because they see our commitment. Correct management of WEEE is fundamental for society, from what we have seen the road is long and we have to work a lot for reach the much-attested “zero waste”, however, in the last decade this issue has increasingly internalized, it has also increased social commitment, and it can be seen that in the various WEEE decrees what was previously a general discipline has always pointed out more. While attention to this issue is growing, we must say that it is still a problematic sector, it is still high misinformation especially in the older age groups, the problem of historical WEEE still persists and the one against zero that results be free only for small-sized waste and in distributors that have certain dimensions in terms of surfaces sale. In any case we must continue to insist and only in this way will we be able to see the results of the numerous sacrifices made in the future, these behaviors are virtuous, the directives, the objectives at community level consider a correct one more and more fundamental .waste management of electrical and electronic equipment, everyone needs to adapt. Businesses, as we have seen, have gods’ advantages of various kinds, therefore they must increasingly adapt and when possible be able to be proactive and acquire first the advantages. The linear model is gradually being set aside due to the excessive production of waste generated by the products once have fulfilled their function. We are moving towards a “circular” redesign to modify the traditional concept of end of life, moving towards the use of renewable energy sources, the elimination of the use of chemicals toxic, and waste reduction thanks to design, materials, and new business models.

The circular approach is necessary, not it is ethically correct to make future generations pay for the damage created to the environment by current generations, we must change the paradigm also exploiting new technologies based on the redesign of materials, on the green growth of the economy and on long-term innovation. To date, only a limited number of countries have taken action to implement the circular economy, more effort is required from all .The European Union should urge more to achieve the objectives even if it is slowed down from the different levels of development of the various countries which prevent complete uniformity. The model of circular economy, which has always followed the company FG ltd bringing advantages and opportunities both to it and to the environment, is a variable that is very close to her heart. Today it is necessary for the company to undertake to

continue the path already undertaken. The ever greater development of this new model on the market will change more and more the appearance of the latter, which will become increasingly interconnected, integrated and globalized with other markets; the growth of secondary raw materials, the entry of players outside the environmental sector, technological progress will make it increasingly difficult to define future boundaries and scenarios.

References

ADR, (2011), European Agreement concerning the International Carriage of Dangerous Goods by Road, Geneva.

Andersen M., (2007), An introductory note on the environmental economics of the circular economy, *Sustainable Science*, **2**, 133-140.

Arfò S., Mulè M., Matarazzo A., Bongiorno V., Giarratana A., (2019), Management and reuse of industrial waste: inert asbestos as a raw material in the construction sector in a circular economy perspective, *Procedia Environmental Science, Engineering and Management*, **6**, 17-24.

Bhuie A., Ogunseitan O., Saphores J., Shapiro A., (2004), *Environmental and Economic Trade-Offs in Consumer Electronic Products Recycling: A Case Study of Cell Phones and Computers*, IEEE International Symposium on Electronics and the Environment, 74-79.

Cooper T., (2004), Inadequate life? Evidence of consumer attitudes to product obsolescence, *Journal of Consumer Policy*, **27**, 421-449.

Cui J., Forssberg E., (2003), Mechanical recycling of waste electric and electronic equipment, *Journal of Hazardous Materials*, **99**, 243-263.

Dalrymple I., Wright N., Kellner R., Bains N., Geraghty K., Goosey M., Lightfoot L., (2007), An integrated approach to electronic waste (WEEE) recycling, *Circuit World*, **33**, 52-58.

Di Bella A., Cannavò A., Giaquinta G., Liardo R., (2019), Exploitation and energy recovery of fluff: smart solutions in a prospective of circular economy, *Procedia Environmental Science, Engineering and Management*, **6**, 95-102.

EC COM 397, (2014), Proposal for a Directive of the European Parliament and of the Council amending Directives 2008/98/EC on waste, 94/62/EC on packaging and packaging waste, 1999/31/EC on the landfill of waste, 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment, Brussels, 2.7.2014.

EC COM 398, (2014), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Towards a circular economy: A zero waste programme for Europe, Brussels, 25.9.2014.

EC COM 98, (2020), Communication from The Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A new Circular Economy Action Plan, For a cleaner and more competitive Europe, Brussels, 11.3.2020.

EC COM 640, (2019), Communication from The Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, Brussels, 11.12.2019.

European Directive 95, (2002), Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, *Official Journal of the European Union*, L 37/19, 13.2.2003, Bruxelles.

European Directive 96, (2002), Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE), *Official Journal of the European Union*, L 37/24, 13.2.2003.

European Directive 12, (2006), Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste, *Official Journal of the European Union*, L 114/9, 27.4.2006, Bruxelles.

European Directive 98, (2008), Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, *Official Journal of the European Union*, L 312/3, 22.11.2008, Bruxelles.

European Directive 19, (2012), Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), *Official Journal of the European Union*, L 197/38, 24.7.2012, Bruxelles.

European Directive 849, (2018), Directive (EU) 2018/849 of the European Parliament and of the Council of 30 May 2018 amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment, *Official Journal of the European Union*, L 150/93, 14.6.2018, Bruxelles.

European Directive 850, (2018), Directive (EU) 2018/850 of the European Parliament and of the Council of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste, *Official Journal of the European Union*, L 150/100, 14.6.2018, Bruxelles.

European Directive 851, (2018), Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste, Official Journal of the European Union, L 150/109, 14.6.2018, Bruxelles.

European Directive 852, (2018), Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste, *Official Journal of the European Union*, L 150/141, 14.6.2018, Bruxelles.

Goosey M., (2014), End-of-life electronics legislation – an industry perspective, *Circuit World*, **30**, 41-45.

Gungor A., Gupta S., (1998), Disassembly sequence planning for products with defective parts in product recovery, *Computer and Industrial Engineering*, **35**, 161-164.

Ingrao C., Selvaggi R., Valentia F., Matarazzo A., Pecorino B., Arcidiacono C., (2019), Life cycle assessment of expanded clay granulate production using different fuels, *Resourseces conservation and recycling*, **141**, 398-409.

Kwak M., Behdad S., Zhao Y., Kim H., Thurston D., (2011), E-waste stream analysis and design implications, *Journal Mechanical Design*, **133**, 101-109.

Legislative Decree 151, (2005), Decreto Legislativo n. 151, 25 luglio 2005, Attuazione delle direttive 2002/95/CE, 2002/96/CE e 2003/108/CE, relative alla riduzione dell'uso di sostanze pericolose nelle apparecchiature elettriche ed elettroniche, nonché allo smaltimento dei rifiuti, *Gazzetta Ufficiale*, n. 175 del 29 luglio 2005 - Supplemento Ordinario n. 135, Roma.

Legislative Decree 49, (2005), Decreto Legislativo n. 49, 14 marzo 2014, Attuazione della direttiva 2012/19/UE sui rifiuti di apparecchiature elettriche ed elettroniche (RAEE), *Gazzetta Ufficiale*, n. 73 del 28 marzo 2014, Supplemento ordinario n. 30/L, Roma.

Legislative Decree 185, (2007), Decreto ministeriale n. 185, del 25 Settembre 2007, Istituzione e modalità di funzionamento del registro nazionale dei soggetti obbligati al finanziamento dei sistemi di gestione dei rifiuti di apparecchiature elettriche ed elettroniche (RAEE), costituzione e funzionamento di un centro di coordinamento per l'ottimizzazione delle attività di competenza dei sistemi collettivi e istituzione del comitato d'indirizzo sulla gestione dei RAEE, ai sensi degli articoli 13, comma 8, e 15, comma 4, del decreto legislativo 25 luglio 2005, n. 151, *Gazzetta Ufficiale*, n. 257 del 05-11-2007, Roma.

Matarazzo A., (2018), *Rough Set Applied to Air Pollution: A New Approach to Manage Pollutions in High Risk Rate Industrial Areas*, In: *Emerging Pollutants Some Strategies for the Quality Preservation of Our Environment*, Soloneski S., Larramendy M.L. (Eds.), IntechOpen, 13-18.

Matarazzo A., Clasadonte M.T., Ingrao C., (2018), The (dominance based) rough set approach applied to air pollution in a high risk rate industrial area, *Environmental Engineering and Management Journal*, **17**, 591-599.

Matarazzo A., Baglio L., (2018), The modern pillars of Circular Economy, *Archives of Business research*, **6**, 228-240.

Peng M., Layiding W., Dong X., Jiangang G., Guanghong D., (2004), *A Physical Process for Recycling and Reusing Waste Printed Circuit Boards*, IEEE International Symposium on Electronics and the Environment, Scottsdale, 24 May 2004, AZ, USA.

Rose C., Beiter K., Ishii K., (1999), *Determining End-of-Life Strategies as a Part of Product Definition*, Proc. of the 1999 IEEE International Symposium on Electronics and the Environment, Danvers, 13 May 1999, MA, USA.

The Ellen MacArthur Foundation, (2013), Towards a Circular Economy - Economic and Business Rationale for an Accelerated Transition, Cowes, On line at: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf.

Tsydenova O., Bengtsson M., (2011), Chemical hazards associated with treatment of waste electrical and electronic equipment, *Waste Management*, **31**, 45-58.

UNI EN ISO 14001, (2015), Environmental management systems - Requirements with guidance for use, On line at: https://www.iso.org/obp/ui/#iso:std:iso:14001:ed-3:v1:en.

UNI EN ISO 9001, (2015), Quality management systems - Requirements, On line at: https://www.iso.org/obp/ui/#iso:std:iso:9001:ed-5:v1:en.

Widmer R., Oswald Krapf H., Sinha-Khetriwal D., Schnellmann M., Boni H., (2005), Global perspectives on e-waste, *Science Direct*, **25**, 436-458.

Yuan Z., Bi J., Moriguichi Y., (2010), The circular economy a new development strategy in China, *Journal of Industrial Ecology*, **10**, 4-8.

Web site:
https://www.fgambiente.com
https://www.footprintnetwork.org