ANALYSIS OF THE E-WASTE MANAGEMENT PRACTICES IN THE CONTEXT OF CIRCULAR ECONOMY

Albăstroiu Irina[1], Bucur Mihaela[2] and Năstase Gabriel[3]
[1) 2)] *Bucharest University of Economic Studies, Romania*
[3)] *Christian University"Dimitrie Cantemir"*, *Bucharest*, Romania
E-mail: irina.albastroiu@com.ase.ro; E-mail: bucur.mihaela@yahoo.com;
E-mail: gabriel.i.nastase2013@gmail.com

Abstract
Quantities of electrical and electronic waste, on a global scale, are growing rapidly. This waste contains materials that can be recovered as secondary raw materials as well as hazardous materials and substances that can become dangerous to environment. In this context, managing electronic waste (or e-waste) is one of the most important problems worldwide.
In this context, our approach takes into account the applicability of the circular economy principles in the lifecycle stages of the electronic products, from manufacturing and delivery to end-of-life and their transformation into waste, in terms of the involvement of key industry stakeholder, consumers, authorities and civil society. This paper highlights the main aspects on how waste should be properly managed at the end of the useful life of the electrical and electronic equipment through recycling and revaluation, reducing as much as possible harmful effects on the environment. Also, this paper presents a brief analysis of the statistical data related to the level of collection and recycling of e-waste in the European Union, in general, and in Romania, in particular. The data indicates that only a small proportion of electronic waste is recycled and recovered.

Keywords
electronic waste (e-waste), electrical and electronic equipment (EEE), circular economy, recycling, environment.

JEL Classification
L63, Q53, Q57.

Introduction

Electronic waste or *e-Waste* is a term used to describe almost all types of electrical and electronic equipment (EEE) (namely, any household or business item with circuitry or electrical components with power or battery supply) that has entered or could enter the waste stream, with reference to all components, subassemblies and consumables which form an integral part of the product when it becomes waste (European Parliament and Council of the European Union, 2012). The partial recyclability of these products, due to their material composition, has led to the development of the recycling and re-use techniques, with particular relevance to waste management, but also to the recovery of embedded valuable materials (Gaidajis, Angelakoglou and Aktsoglou, 2010). As a result, the e-waste disposal

issue has attracted the interest of politicians, non-governmental and business organizations and the scientific community.
In such a context, this paper highlights the various sources of e-waste (WEEE – waste of electrical and electronic equipment), management strategies for e-waste and disposal methods, but also presents a brief analysis of the ecological measures for the treatment of EEE and the results obtained from their application in Europe, in general, and in our country, in particular (Özmen et al, 2017).

1. E-Waste Management Approaches

Detailed and comprehensive analysis and evaluation of waste generation and treatment form the basis of designing and assessing policy instruments for the circular economy (Tisserant et al., 2017). Pearce and Turner (1990), researchers who first used the term *circular economy*, show that, traditionally, the economy did not pursue recycling and treated the environment as a reservoir of waste. But things have to change, and the planet must be seen as a closed economic system, where the links between the economy and the environment are not linear, for a win-win relationship between the two, proposing a closed-loop of the materials in the economy (Su et al., 2013). Thus, a new approach is also needed for electrical and electronic equipment, both to extend their lifetime through repairing, reusing, refurbishing, recycling and remanufacturing and to reduce the negative environmental impacts when these products reach the end of their life and there is a need for proper waste management, especially since the consistent emergence of new "intelligent" models, functions and technologies over the last 20 years causes the rapid obsolescence and their lifetime has been substantially reduced (Kiddee, Naidu and Wong, 2013).
Electrical appliances are manufactured from a wide range of materials, including precious metals (such as gold and platinum), toxic heavy metals, metallic integrated circuits, mixed plastics, flame retardants and glass. The danger associated with EEE consists mainly of chemical elements containing heavy metals (Hg, Cd, Pb), toxic gases (freon) or non-biodegradable materials (plastic, glass, metals) with serious environmental and health effects if they are not collected separately and recycled according to the standards. The ideal case is when e-waste or their components are reused. Heavy metals - lead, cadmium, mercury and arsenic - as well as flame retardants can cause environmental contamination by leakage from landfills into watercourses. By recycling, this type of contamination can be avoided, and useful resources can be preserved, as up to 95% of the materials can be recovered for reuse.
A hierarchical *waste management system* (such as the system proposed by European Union through *Directive 2002/96/EC*) is based, first of all, on preventing and minimizing waste at source as much as possible. However, if this first option is not applicable, waste must be directly reused (spare parts and components are removed from devices and, with some modifications, are used to produce other), recycled (components and ingredients are collected and sent to manufacturing companies producing similar components) or reprocessed (in a form that turns it into a secondary source of "raw materials"). When recycling (material recovery) is not possible, at least the energy incorporated in the waste should be recovered for use as "alternative energy". When waste cannot be processed through any of the above options, the solution remains the controlled disposal. The main *disposal methods* are (Patil and Sharma, 2015): land filling (this method is suitable for a small quantity of electronic waste (for local and small users), when e-waste is stored and covered with other household/domestic waste and soil) and incineration (electronic waste is burned in controlled environment, but gases or toxic emissions are released into the atmosphere).
The globalized market for end-user electronics offers both challenges and opportunities related to circular economy. There are opportunities for producers, distributors, consumers

and authorities to work together for a greater sustainability, but this can be a considerable challenge.

From the *manufacturers' perspective*, there is a high potential in designing modular products (as is the case of the Dutch company *Fairphone*, which launched in 2013 the first modular mobile phone), that can facilitate easier component exchange and can be more easily repaired and recycled; encouraging reuse, shared use, leasing systems; collection, dismantling and safe recycling of products containing critical materials (such as rare earths in electronic devices) (European Environment Agency, 2014). Major industry companies have integrated the principles of circular economy into their work. For example, *Dell* is collaborating with various organizations to enable consumers to recycle e-waste free of charge in 78 countries, has release the first computer made with plastic recycled from old electronics (*OptiPlex 3030 All-in-One*), use annually more than 4 tons of recycled materials from their own products (Dell, 2016); *Hewlett-Packard (HP),* through its *HP Planet Partners* program, facilitates the recycling of its products (especially printer cartridges) in all countries where the organization is present, and through its *HP Managed Print Services* program supports the shift from the sale of printers to printing service and leasing (HP, 2016); Philips designs products that allow multiple life cycles with minimal value, quality and energy loss, encourages material recovery and reuse, and through *Refurbished Systems* business unit, the company refurbishes, improves and resells products (especially medical devices) at attractive prices (Philips, 2014).

However, not only electronics manufacturers have to follow these directions in approaching the circular economy. For example, waste management can not be carried out as an exclusive task of collective producer organizations, but involves both *central and local authorities*. To this end, there must be a coherent legal framework, public door-to-door collecting services must function well, integrated with appropriate facilities (such as municipal collection centers where private households will hand over e-waste free of charge), while information and education of the civil society must be also done with the involvement of state institutions and organizations.

Also, the *economic operators* who are directly involved in the collection, treatment, recycling, recovery and elimination of electrical and electronic equipment waste have the obligation to identify and to include categories and codes of e- waste according to the norms in force for selective collecting.

To the same extent, *consumers* need to be well informed and educated regarding the problems of e-waste, because precisely through in-depth knowledge, we educate ourselves and others (by the power of example) to create a clean, healthy and efficient living environment for a better future.

2. E-Waste in Europe and Romania. Comparative perspective

For the European Union, the field of e-waste is a priority, requiring all member states to integrate and implement specific measures based on the developed directives.

According to "*The Global E-waste Monitor 2017 Executive Summary*", in Europe, at the level of 2016, the e-waste generation reached 12.3Mt, which meant approximately 16.6 kg on average per citizen (Baldé et al., 2017). The highest quantity in Europe was registered by Germany, whose inhabitants generated 1.9 Mt in the year under analysis, closely followed by Great Britain, which generated 1.6 Mt and by Russia which reached 1.4 Mt. At the same time, the highest quantity of e-waste per inhabitant in Europe is generated by Norway, 28.5 kg per inhabitant, followed closely with 24.9 kg per inhabitant by both Great Britain and Denmark. In terms of the e-waste management practices, the most advanced ones at the international level are those applied by Europe, more precisely the Northern Europe: Switzerland, Norway, and Sweden. In their case, the collection rate reaches 49%, thus occupying the first position in the world.

Recycling rate of e-waste for the period 2011-2015 is presented in the figure no. 1.

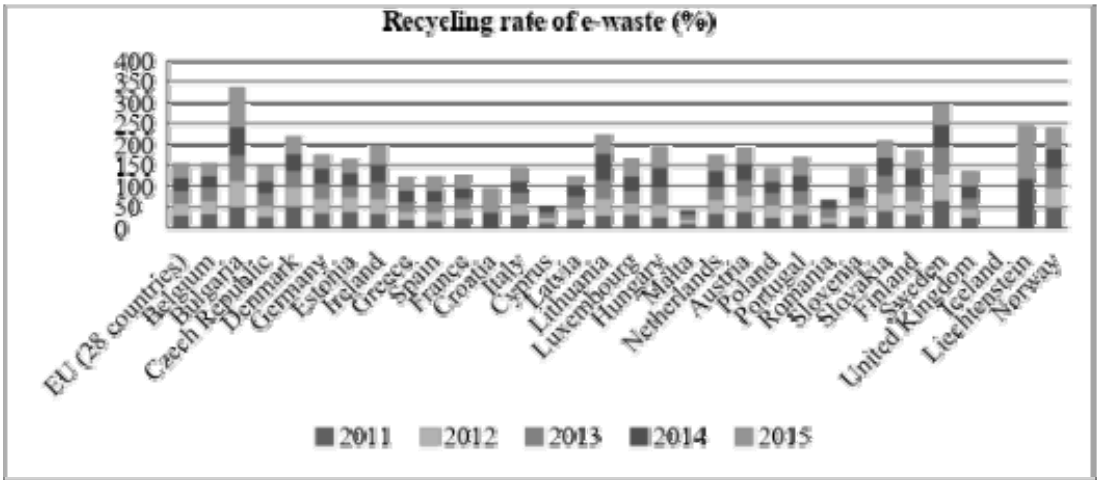

Fig. no. 1. Recycling rate of e-waste (%) in 2011-2015
Source: Eurostat, 2015

Although Bulgaria appears to have a high collection rate, the reality is quite different. Actually, the volume put on the market is underestimated, and this will lead to a decline in 2016 due to changes in the national legislation. For Romania, for 2015 there is no statistical data available (on Eurostat). However, in 2014, our country is situated as having a recycling e-waste rate between 11.5% and 26.5%, therefore at the lowest rate, according to the map below (figure no. 2).

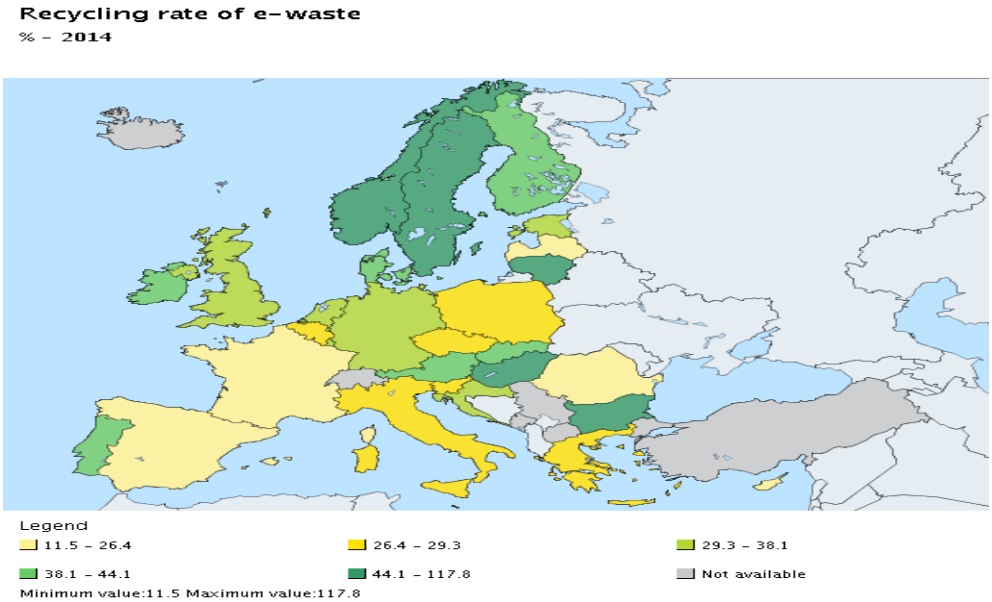

Fig. no. 2. Recycling rate of e-waste
Source: Eurostat, 2015

In 2014, Electrical and electronic equipment (EEE) put on the market, by category in Romania is presented in the figure no. 3. The first three positions are occupied by large household appliances (60,9%), consumer equipement (10,6%) and IT&C (9,6%).

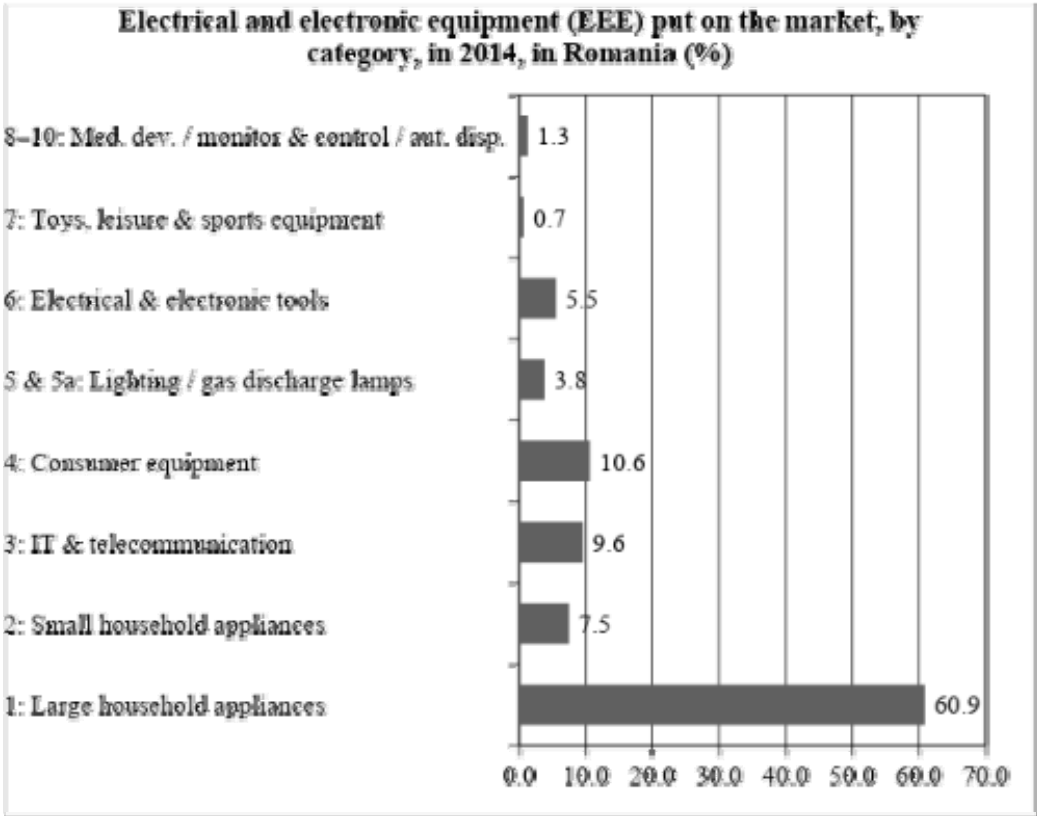

Fig. no. 3. Electrical and electronic equipment (EEE) put on the market, by category in Romania, in 2014 (%)
Source: Eurostat, 2015

The amounts of *domestic e-waste* generated are being grouped around six e-waste categories (Baldé et al., 2017): small IT; temperature exchange equipment; screens, monitors and lamps; large equipment; small equipment; telecommunications equipment. Each product of the six e-Waste categories has a different lifetime profile, which means that each category has different waste quantities, economic values, as well as potential environmental and health impacts, if recycled inappropriately. Consequently, the collection and logistical processes and recycling technology differ for each category, in the same way as the consumers' attitudes when disposing of the electrical and electronic equipment also vary (Balde at al., 2017).
According to "The Global E-waste Monitor 2017 Executive Summary", the *domestic e-waste* generated in 2016 (kg/inh) in Romania was of 11.6 kg per inhabitant, meanwhile the domestic e-waste generated in 2016 (kt) was of 229 kt (Baldé et al., 2017).
Although progress has been made and the WEEE system has been adapted to EU legislative changes, as much as possible, the quantities of WEEE collected are far from the EU target of collecting 4 kg per capita (under Directive 2002/96/EC) despite the efforts of public authorities and responsible operators.
Table no. 1 shows the e-waste collected in Romania, between 2011-2014 (for 2015 there is no data yet).

Table no. 1. WEEE collected in Romania, between 2011-2014

WASTE (in tones)	2012	2013	2014	2015
Automatic dispensers	57	150	65	:
Consumer equipment and photovoltaic panels	3.514	4.672	3.513	:
Consumer equipment	:	:	:	:
Photovoltaic panels	:	:	:	:
Electrical and electronic tools	692	703	815	:
IT and telecommunications equipment	4.976	4.886	4.803	:
Large household appliances	11.399	20.316	20.465	:
Lighting equipment	511	409	542	:
Gas discharge lamps	266	428	598	:
Medical devices	58	28	34	:
Monitoring and control instruments	687	506	236	:
Small household appliances	864	977	1.021	:
Toys, leisure and sports equipment	60	90	66	:
Total Waste	**23.083**	**33.165**	**32.159**	**:**

Source: Eurostat, 2015

Figure no. 4 shows the amount of WEEE collected by Romania in kg per inhabitant for the years 2008 and 2014. It can thus be observed the separate collection of Romania in 2008 and in 2014, as well as the progress made between these periods.

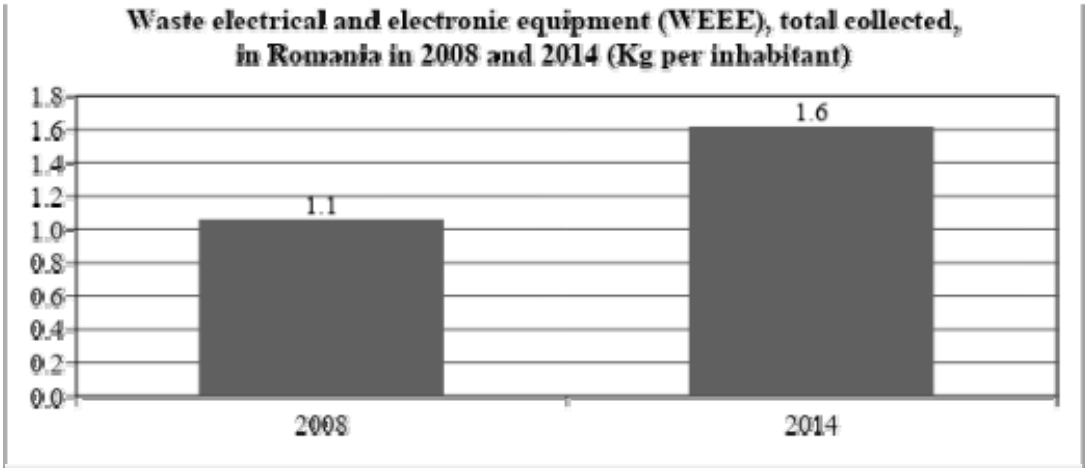

Figure no. 4: E-waste collected in Romania in 2008 and 2014 (kg per inhabitant)
Source: Eurostat, 2015

Thus, if in 2008, the total collected waste electrical and electronic equipment (WEEE), in Romania was of 1,1kg per inhabitant, in 2014, total collected WEEE was 1,6 kg per inhabitant. However, in spite of this progress, Romania still ranked the last place in 2014 among EU Member States, the first rank being occupied by Sweden with14.7 kg per inhabitant.

The poor results recorded by Romania are mainly the effect of the lack of implementation of a municipal waste selective collection system at source and the very low awareness among population about the beneficial effects of selective collecting system.

The most important change in the waste recycling market for electrical and electronic equipment in Romania was the transposition of *Directive 2012/19/EC* into national

legislation through *Emergency Ordinance no. 5/2015* (Government of Romania, 2015) which establishes extended producer responsibility, implying an environmental policy approach whereby a manufacturer's liability for his product is extended to the post-consumption stage of the product's life cycle. The desired *ecological measures* in the EEE process are represented by methods such as: dismantling waste and neutralizing hazardous substances; dismantling and reuse of components; dismantling and recycling of materials; incineration in order to obtain energy; removal of remaining non-hazardous substances.
However, in the current situation, without the *involvement of local authorities* to take over electronic waste from the population, the practice is particularly difficult because, in the absence of bonuses, buy-backs or coupons, the population does not deliver free of charge the old refrigerator or washing machine.
The *lack of infrastructure* is another critical factor limiting the collection of WEEE. The Romanian management system needs improvements to meet the European Directives requirements. Apart from the fact that key actors should be educated to promote an eco-friendly e-waste approach, it is also important to have a well-established *system for collecting e-waste*, namely a collection system that has to be easy to use by consumers and must provide the comfort that can stimulate them to properly dispose of old electrical and electronic equipment.
Also, in the absence of the *National and Regional Waste Management Plans*, the achievement of the recycling target for 2020 (from January 2016, the annual collection and recycling target for WEEE of 4 kg per capita has been replaced by a 40% rate and will gradually increase to 65% in 2020**)** will most likely be delayed, and steps are needed to accelerate compliance efforts on the ground. Our country has requested and obtained special national exemptions from the collection rates imposed by the European directives due to the lack of necessary infrastructure and the low level of consumption of electrical and electronic equipment.Nevertheless. these ambitious collection targets must be based on data on the amount of WEEE generated, but must also take into account the different product lifecycles, the income of the population, the lack of selective collection services and the actual availability of waste in the market to be collected.

Conclusions

To create an *efficient management system for waste*, some major elements are needed, namely: collection infrastructure, recycling, industry involvement in support recycling activities, awareness and eventual incentive for users to delivery of such products and, finally, creation of monitoring and reporting systems. The implementation of an efficient waste management system varies from one state to another or, in some cases, from one community to another, being influenced by a number of factors such as political will, the legislative and economic system, as well as differences in culture and social consciousness.
As it can be seen, there are major variations in the collected WEEE amounts in the European Union, reflecting important differences in WEEE consumption levels but also various levels of performance as far as the waste collection schemes are concerned.
In spite of its progress, Romania continues to rank the last place in terms of WEEE kg per inhabitant, as well as in other similar aspects. Achieving high recycling performance is not possible without a concerted approach by all actors involved: central authorities responsible for implementing and implementing legislation, local authorities in charge of setting up municipal collection centers, sanitation operators, collective organizations, companies that accept to assume the environmental obligations, but also the active participation of civil society. We need to be aware that the implementation of the *selective collection system* at source and the *disposal* of landfill of municipal waste should start immediately, otherwise it will be impossible to achieve the assumed objectives. It is time for each of us to understand the determinant role in the recycling chain and to respect our obligations as citizens and

protect the environment by responsible waste disposal without waiting for incentives for what should be a normal behavior.

References

Baldé, C.P., Forti V., Gray, V., Kuehr, R. and Stegmann,P., 2017. *The Global E-waste Monitor – 2017*. Bonn/Geneva/Vienna: United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA).

Dell, 2016. *Dell on the Circular Economy*. [pdf] Dell. Available at: <http://i.dell.com/sites/content/corporate/corp-comm/en/Documents/circular-economy-0316.pdf> [Accesed 19 April 2018].

European Environment Agency, 2014. *Environmental Indicator Report 2014. Environmental Impacts of Production-Consumption Systems in Europe.* [online] European Environment Agency. Available at: <https://www.eea.europa.eu/publications/environmental-indicator-report-2014> [Accessed 18 April 2018].

European Parliament and Council of The European Union, 2012. *Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE*). 4 July 2012. [online] European Parliament and Council of The European Union. Available at: <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32012L0019> [Accesed 19 April 2018].

Eurostat, 2015. *Recycling rate of e-waste.* [online] Eurostat. Available at: < http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rt130&plugin=1> [Accesed 19 April 2018].

Gaidajis, G., Angelakoglou, K. and Aktsoglou, D., 2010. E-Waste: Environmental Problems and Current Management. *Journal of Engineering Science and Technology Review*, 3(1), pp.193-199.

Government of Romania, 2015. Emergency Ordinance no. 5/2 April 2015 on Waste of Electrical and Electronic Equipment. [online] Government of Romania. Available at: < http://www.cdep.ro/pls/legis/legis_pck.htp_act?ida=129734> [Accessed 18 April 2018].

Hewlett-Packard (HP), 2016. *5 Ways to Take Part in the Circular Economy*. [online] HP. Available at: <http://www8.hp.com/h20195/v2/getpdf.aspx/4AA6-6733ENW.pdf?ver=1.0> Accessed [18 April 2018].

Kiddee, P., Naidu, R. and Wong, M., 2013. Electronic Waste Management Approaches: An Overview. *Waste Management*, 33, pp.1237–1250.

Özmen, Ö., Sârbu, R., Săseanu, A.S. and Toader, C., 2017. The European Foundation for Quality Management (EFQM) Excellence Model in a Low Voltage Switchgear Company. *Amfiteatru Economic*, 19(Special No. 11), pp. 1064-1076.

Patil, S. and Sharma, N., 2015. Electronic Waste - A Literature Review. *International Journal of Science and Research*, 4(4), pp.1622-1624.

Pearce, D.W. and Turner, R.K., 1990. *Economics of natural resources and the environment*. Herts: Harvester Wheatsheaf.

Philips, 2014. *Rethinking the Future. Our Transition towards a Circular Economy*. [pdf] Philips. Available at: <https://www.philips.com/c-dam/corporate/about-philips/company/downloads/circular-economy-brochure.pdf> [Accesed 19 April 2018].

Su, B., Heshmati, A., Geng, Y. and Yu, X., 2013. A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, 42, pp.215-227.

Tisserant, A., Pauliuk, S., Merciai, S., Schmidt, J., Fry, J., Wood, R. and Tukker, A., 2017. Solid Waste and the Circular Economy: A Global Analysis of Waste Treatment and Waste Footprints. *Journal of Industrial Ecology*, 21(3), pp.628-640.