World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:11, No:2, 2017

Quantification of E-Waste: A Case Study in Federal University of Espírito Santo, Brazil

Andressa S. T. Gomes, Luiza A. Souza, Luciana H. Yamane, Renato R. Siman

Abstract**—**The segregation of waste of electrical and electronic equipment (WEEE) in the generating source, its characterization (quali-quantitative) and identification of origin, besides being integral parts of classification reports, are crucial steps to the success of its integrated management. The aim of this paper was to count WEEE generation at the Federal University of Espírito Santo (UFES), Brazil, as well as to define sources, temporary storage sites, main transportations routes and destinations, the most generated WEEE and its recycling potential. Quantification of WEEE generated at the University in the years between 2010 and 2015 was performed using data analysis provided by UFES's sector of assets management. EEE and WEEE flow in the campuses information were obtained through questionnaires applied to the University workers. It was recorded 6028 WEEEs units of data processing equipment disposed by the university between 2010 and 2015. Among these waste, the most generated were CRT screens, desktops, keyboards and printers. Furthermore, it was observed that these WEEEs are temporarily stored in inappropriate places at the University campuses. In general, these WEEE units are donated to NGOs of the city, or sold through auctions (2010 and 2013). As for recycling potential, from the primary processing and further sale of printed circuit boards (PCB) from the computers, the amount collected could reach U$ 27,839.23. The results highlight the importance of a WEEE management policy at the University.

Keywords**—**Solid waste, waste of electric and electronic equipment, waste management, institutional generation of solid waste.

I. Introduction

ECONOMIC development, industrialization, local social habits, location and climate highly influence the rate of Urban Solid Waste (USW) generation. Usually, higher economic development and urbanization leads to a higher waste generation [1]. Nowadays, there are more than 206 million Brazilian citizens engender USW [2], what caused an estimated generation of 78.6 million tons approximately in 2014 and this would produce an increase of 2.9% in comparison to 2013 [3]. One of the biggest challenges of modern society is to address the excessive generation, bearing in mind destination (treatment, reutilization and recycling) and environmentally safe final disposal of the waste.

A. S. T. Gomes and L. A. Souza are graduation students at Environmental Engineering Department with the Federal University of Espírito Santo, Brazil, 29075-910. (e-mail: andressa.siegle@hotmail.com, luizaazevedos@hotmail.com).

L. H. Yamane is with the Environmental Engineering Department, Federal University of Espírito Santo, Brazil, 29075-910 (e-mail: luciana.yamane@ufes.br).

R. R. Siman is with the Environmental Engineering Department, Federal University of Espírito Santo, Brazil, 29075-910 (corresponding author to provide phone: +55 27 3335-2676; e-mail: renato.siman@ ufes.br).

The composition of Urban Solid Waste varies from country to country. It depends on economic status, industrial structure and the regulations governing the waste management [4]. Some typical materials on the composition of waste such as rags, leather, cloths, rubber and electronic waste [5].

According to the Associação Brasileira de Desenvolvimento Industrial (ABDI), which is a Brazilian Association of Industrial Development [6], electrical and electronic equipment are all those products whose operation depends on the use of electric current or electromagnetic fields. At the end of their useful life are considered WEEE [6].

The production of WEEE comes up with the global development trend. The rate of generation of WEEE in the world increases 5% per year [7]. In a report published by the United Nations University (UNU), the estimated generation in 2014 was 41.8 million tons of WEEE in a global scale. From those 41.8 million, 3 million tons were composed by technology and information equipment such as laptops, tablets and smartphones. A projection for 2018 indicates the generation of 50 million tons of WEEE [8]. Developing countries will discard 400-700 million computers by 2030, while developed countries will discard 200-300 million [9].

The electronics industry illustrates the fast production dynamics, due to the increasing consumption and the corresponded waste generation [10]. It occurs rather than only because of the fast technological development and the expansion of the market, but due to the trend of shortening of the useful lifetime of electronics equipment, called programmed or planned obsolescence [10]. In addition, the increasing volume generation of WEEE, combined to its complex composition, creates difficulties to their treatment and disposal [10].

WEEE is considered toxic to human health and to the environment because it often has harmful compounds in its composition [11]. The lack of worldwide solution for electronic waste treatment and the environmental concerns of illegal recycling practices justify and offer an increasing incentive for further studies to enlarge recycling practices and legal disposal [12].

Electronic equipment can present in their composition up to 60 different elements, from valuable to dangerous ones [13]. The metals found on WEEE embrace copper, iron, nickel, aluminum, lead and zinc [14]. The precious metals are silver (0.2%), gold (0.1%) and palladium (0.005%) and are shaped as thin film over other base metals and ceramics [14].

The quantity of valuable metals found on WEEE is significant, considering that the concentration of gold present on the Printed Circuits Board (PCB) is higher than the concentration found on crude gold ore [15]. The Printed Circuits Board is component of most electronic equipment (computers, televisions, VCRs, DVDs, cell phones, printers, etc.) [15]. PCBs are of great interest for being considerate secondary feedstock rich in copper and precious metals, such as gold, silver and palladium [16].

The use of Reverse Logistics (RL) for the management of WEEE is a valuable tool to social and economic development. According to the ABDI [6], RL enable collection and refund of the waste to their manufacturer, either for their reuse and use in another productive cycle or for an appropriate final disposal. Succeeding this model is essential to Brazilian development, considering the increasing consumption of electronic products, such as cell phones, computers, and its proportional generation of WEEE in the end of their useful lifetime [17].

WEEE generated from institutions, such as universities, has different logistic flows than houses and industries [17]. Institutional generation flow comprehends WEEE from public and private institutions, including companies of different areas. Domicile generation flow comprehends WEEE from residencies [18].

The aim of this work is to perform a diagnosis of the actual WEEE scenario on the UFES, as well as identify generating sources, temporary storing location and potential recycling destination.

II. Methodology

Four campuses located in the Estate of Espírito Santo, Brazil, compose UFES. The largest one, which presents the greatest variety of courses, is situated in the city of Vitória, in the neighborhood of Goiabeiras. Also located in Vitória, the campus in the Maruípe neighborhood is focused on health studies. The campus located in the city of São Mateus is called North University Center of Espírito Santo (CEUNES). Lastly, the campus located in the city of Alegre is called Center of Agricultural Sciences (CCAE), which attend the south area of Espírito Santo with courses focused on the agrarian and livestock's development of the region. Summing up, UFES offers 4670 career opportunities in 105 graduation courses, 58 master's courses and 26 doctoral degree courses. There are 1696 teachers, 2072 technical-administrative servers, 18559 students on graduation courses on campus, 1852 students on distance learning graduation courses and 3176 students enrolled in masters or doctoral degree courses.

The choice of UFES campuses as study area is justified because of their potential in generating WEEE, especially due to computer labs and administrative areas that intensively discarded end-of-life data processing and communication's equipment. Support equipment for classes, such as projectors and computers are also constantly replaced. Laboratories used for practical classes and research demand several laboratorial electrical equipment, used to measure chemical, biological and physical parameters. Those and other equipment used in diverse research programs on the University are also relevant for WEEE generation.

The equipment after being discredit as belonging to the University, they are forwarded to a storage shed located on Goiabeiras campus.

(a)

(b)

Fig. 1 Storage shed of Goiabeira's campus (a) external view; (b) internal view

A. Diagnostic of WEEE Generation on UFES Campuses

Diagnostic of WEEE generation on UFES campuses were performed by two steps: Firstly, survey of the WEEE management scenario and the quantification of WEEE production, as it follows:

1. WEEE Management's Current Scenario at UFES Campuses

In order to register and control UFES's patrimony, there is an identification for all equipment, furniture and general material goods, which give them a register numbers. This control is common in all public entities. Considering electronical equipment, when their useful lifetime is ended, they go through a process of discredit followed by a routing to a temporary storage shed.

For the analysis of the current WEEE management on UFES campuses three main information was collected: WEEE generation potential sources, location for temporary storage and potential recycling destination.

The information was collected from November/2015 to August/2016. This information was obtained through phone calls, face-to-face interviews and field research.

The patrimonial section was responsible for the authorization to access the temporary storage shed monthly, in Goiabeiras campus. Other information was required about collection, frequency of collection, transportation, temporary or definitive storage, internal movement, donations and auctions.

2. Quantification of WEEE Generation on UFES Campuses

The quantification of WEEE generation on UFES campuses were performed through data analysis from 2010 to 2015.

For the period from 2010 to 2015, the patrimonial section of UFES Goiabeiras campus provided a spreadsheet containing information from equipment discredit, donation and auctions. The WEEE were classified according to a triage pre-stablished by University patrimony.

B. Potential Recycling/Contamination Potential from WEEE Generated on UFES Campuses

The recycling potential of each WEEE present on the shed was defined from their quantity and destination options: Recycling, primary processing and reuse. WEEE such as computers, printers, LCD monitors and others contain in their composition elements such as printed circuit boards, that presents high benefit. Beyond that, there are other recyclable components.

C. Identification of WEEE Management Alternatives on UFES Campuses

Identifying the appropriate WEEE management approach depends on quantitative and qualitative classification of the waste. Bearing this in mind, with the goal of identifying alternatives for the WEEE management on UFES campuses, a data survey from electronical equipment donated or auctioned from 2010 to 2015 were implemented.

From the analysis of each WEEE, actions can be proposed for improving the WEEE management on UFES campuses.

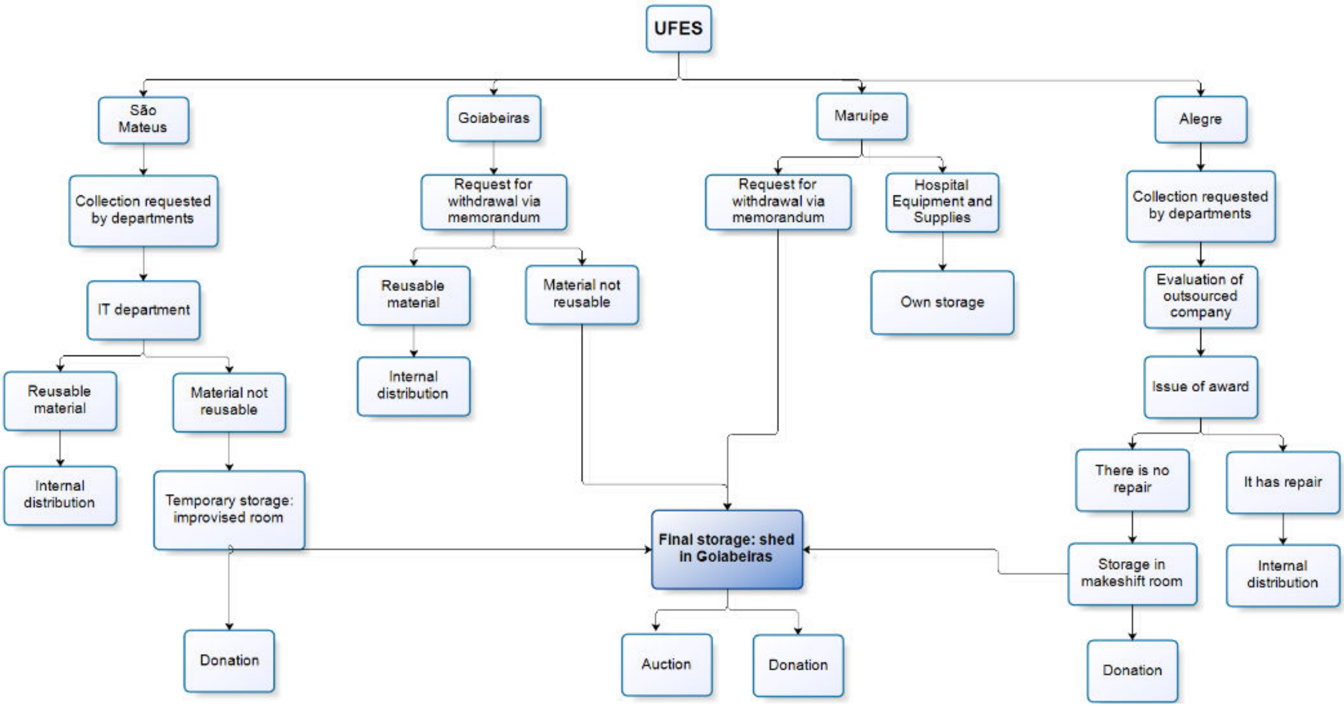

Fig. 2 WEEE management in UFES campuses

III. Results and Discussion

A. WEEE Generation Diagnostic on UFES Campuses

The WEEE generation diagnostic on UFES campuses revealed that only Alegre and São Mateus, two out of four campuses, proceeds correctly an evaluation to determine the reutilization of obsolete or broken electronical equipment. In case of demand for electronical equipment from any department, the reuse of electronical equipment from the storing is recommended on this campus. The largest campus, Goiabeiras, does not perform this process of evaluation.

The State University of São Paulo (UNESP) creates a WEEE Recycling Polo (PREEL), which aims to address correctly social, and ecologically the WEEE generated on campus. After collection, out-of-use computers are routed to a triage, where components are separated for being applied on reassembly of new computers [19]. Initiatives like this could be a possibility to reuse the WEEE on UFES campuses.

The results obtained on each stage are presented as follows.

1. Current Scenario of WEEE Management on UFES Campuses

Firstly, the diagnostic of WEEE generation on UFES campuses identified the current scenario of management of WEEE. A block diagram, presented on Fig. 2, was drawn up from information obtained from a questionnaire, to illustrate how the WEEE management is performed.

The WEEE management inside the university, as expected, includes the stages of collection, transport, storing and reutilization (partially). Therefore, the treatment and final destination take place after the donation or auction, being out of this research scope.

Collectors from Goiabeiras campus are also responsible for the collection on Maruípe campus. The removal is requested by the department through a memo and by arrival order of request and then the WEEE is collected. The equipment that presents utility are redistributed internally. The obsolete equipment is transported to the Goiabeiras campus storage shed for temporary storing. The hospital equipment from Cassiano Antonio de Moraes University Hospital (HUCAM) has their own differentiated storage destination on Maruípe campus. Thus, the WEEE from Goiabeiras and Maruípe campuses are kept stored waiting for auctions and donations.

On São Mateus Campus, the department requests the collection of electronical equipment, which are transported afterwards to a temporary storage basement. Secondly, the electronical equipment is addressed to a computing department to be evaluated for reuse. The equipment considered waste is forwarded to a temporary storage on campus. Once collected, the WEEE is kept in an improvised warehouse until the collection from the patrimonial sector from Goiabeiras campus. However, there is a lack of the control of transport of WEEE forwarded from São Mateus to Goiabeiras, as well as quantity and frequency of collection.

On Alegre campus, the department requests the removal of electronical equipment. An outsourced company evaluates and issues a report of functionality. The electronical equipment considered waste is addressed to an interim deposit and only one donation since 2010 were performed. The major difficulty found on this stage of the diagnostic was the information achievement, for example, the registers of WEEE quantity, collection frequency and others. From the responsible sections, the main difficulty according to the staff and the public servers was the lack of infrastructure to classify and store the WEEE. Another point noticed was the lack of staff to accomplish this service.

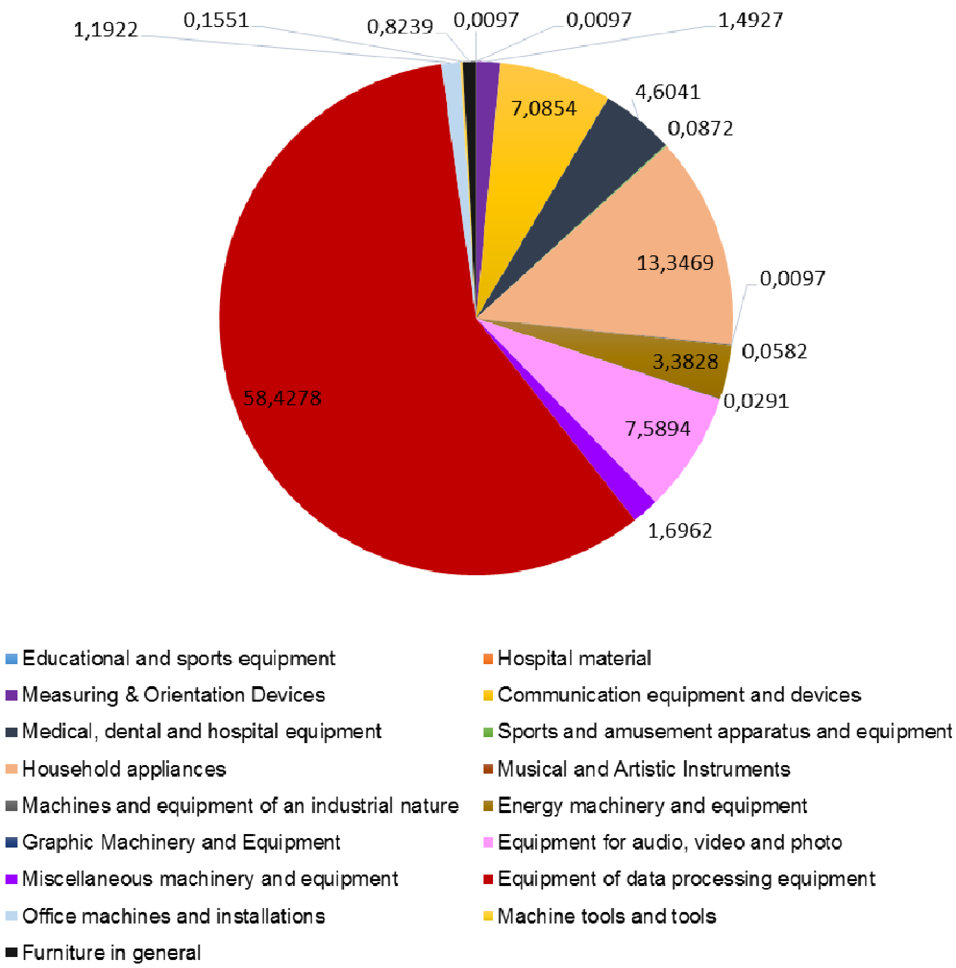

Fig. 3 Categories of WEEE generated in the UFES in percentage between 2010 and 2015

The electronical equipment is stored in locations of precarious conditions, which could result in a major damaging to the equipment, and consequent impossibility of reuse.

The inventory of WEEE, made from data of auctions and donations, do not enable the control of stored equipment. When in the moment of donation or auction, an actualization of status would also be made for the equipment.

The Patrimonial Division takes the last activities on WEEE management generated on UFES (Fig. 2). There are two ways to perform undo and alienation of goods: Auction or donations.

Two auctions took place in the period from 2010 to 2015, one in 2010 and the other in 2013, according to the data survey. Thirty-four donations were performed in the same period. In general, the patrimonial section of the university donates for community organizations. The auction in 2010 raised a total of $51,316.86 and the auction in 2013 raised $82,890.21, converted from real to dollar with the quotation of 01/01/2017: 1 real = 3.1970 dollar.

2. Quantification of Data of the Period from 2010 to 2015

According to the data provided by the patrimonial sector of Goiabeiras campus, from 2010 to 2015, the WEEE was separated in categories according to the patrimonial write-off sheet (Fig. 3). The results are expressed in percentage of unity, non-considering the weight of the waste.

According to Fig. 3, there are 17 identified categories of WEEE used by the university donated or auctioned from 2010 to 2015. The data processing equipment totaled 6028. This category includes keyboards, video monitor, computers, laptops, printers, modem, media converter, CD players, scanners, disk drive, no break, video camera, CD recorder, mouse, switch, wireless adapter, fax, image digitalization machine, etc. Fig. 4 presents the quantity of each WEEE generation, from 2010 to 2015, related to the category of data processing equipment (unity).

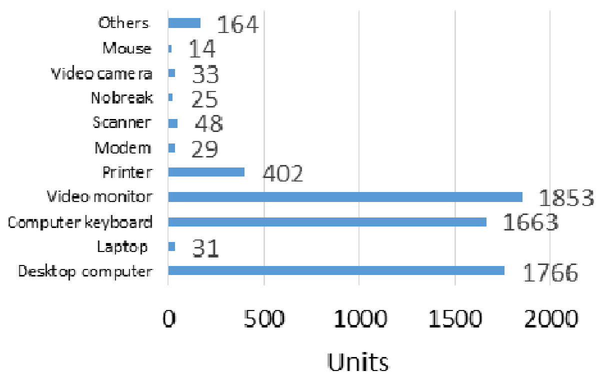

Fig. 4 Quantity of WEEE generated in the category - data processing equipment (2010-2015) in units

According to Fig. 4, the three WEEE accumulated in greater quantities from 2010 to 2015 are video monitors, computers and keyboards, as expected, for being three parts of a hole. However, another equipment such as mouse and no break, which are also used in computer stations, stand out as the two WEEE with lower quantity generated, probably due to reuse, although they are not shown in Fig. 4.

Considering only the most significant category of electric and electronic equipments, data processing equipment, an indicator of WEEE generation was calculated from the average weight of the residues present in this category. The indicator of WEEE generation at UFES was calculated and the information used in this calculation is set out in Table I.

TABLE I
INDICATOR OF WEEE GENERATION

Incoming Students at UFES		Quantity of WEEE - data processing equipment category		Average weight of EEE (kg)	Total weight (kg)
2010	4475	Computer Desktop	1766	29.260*	51,673,160
2011	4858	Notebook	31	2.368	73,408
2012	4533	Keyboard	1663	0.443	736,709
2013	4303	Video Monitor	87	2.00	174,000
2014	4524	Printer	402	6.312	2,537,424
2015	4403	Modem	29	0.200	15,080
Total	**27096**	Scanner	48	3.100	148,800
		Nobreak	25	7.00	175,000
		Video Camera	33	0.225	7,425
		Mouse	14	0.140	1,96
					Total – 55,542,966

Source: [20]; [6]; [21]. * weight CPU and screen.

The total weight of WEEE would be 55,542.966 kg, according to Table I, and the total of students of the university is 27,096, with this, the calculated generation indicator showed that each student generates in average 2.05 kg of WEEE over of his permanence in the university. Table II shows results obtained by different researches [19], [22], [23].

TABLE II
RESULTS OBTAINED BY DIFFERENT STUDIES

WEEE category	[22] Quantity of WEEE in 2 years	[23] Quantity of WEEE in 10 years	[19] Amount of momentary WEEE
Monitor	264	-	13
Printer	169	-	6
Computer Desktop	591	6685	8
Keyboard	-	-	10
Mouse	-	-	16
Laptop	-	-	2
Others	-	-	21

According to Table II, the WEEE generation from data processing equipment at UFES is higher than the generation from [22]. This result is probably due to the period of sampling of 5 years. Regarding [23], which used a period of 10 years, the result is consistently higher in comparison to WEEE generated on UFES. This can also be related to the different structure of each education institution.

Andrade et al. [22] carried out research about generation and final destination of WEEE from Higher Education Institution located in Natal, Brazil, reported that only stage of WEEE management fulfilled is reuse, due to financial reasons.

Another clarified point was that accounting of WEEE from 2007 to 2009 is deficient and only performed by 2 institutions.

Presented quantitative data regarding a questionnaire applied to teachers. The result was 76 equipment in disuse [19]. The main equipment were computers, keyboards, printers, mouse, monitors, laptops, etc. The results from UFES, in despite from Camargo studies, were obtained from information on casualties in the period of 5 years. Although, despite the difference regarding the quantity of waste, it is noticed that the main WEEE match on both Universities. The computer was considered equivalent to the laptop.

From the studies [19], [22] and [23] note the necessity of quantitative numbers of WEEE generation on Universities. This numbers are essential for the implementation of an appropriate WEEE management. Another important point was the WEEE recycling significance, mostly of PCB, due to its high economic value.

B. Identification of recycling potential of WEEE on UFES campuses

1. Computers

From the diagnostic performed, computer is one of the main WEEE generated by the university. PCB are part of them and can easily be found on this WEEE [15]. The activity of PCB recycling became none only viable, but lucrative, due to the metals found on them. This value justifies the approach from [23] to those boards.

To estimate UFES generated WEEE recycling potential, the category of data processing equipment taken in consideration due to their higher quantity.

In the period from 2010 to 2015, the University generated 1766 computers. On the computer case exists a set of printed circuit boards, such as motherboard, network card, modem board and video board [24]. Each computer presents at least four printed circuit boards. The average price of internal circuit board scrap is U$ 5.53 per kilogram [25], in Brazil. Based on the quantity of computers that were discredited from UFES (2010-2015), the value collected from the sale of the PCBs was estimated. Table II presents the estimative.

According to Table III, the estimated value with the sale of PCBs from scrap computers from UFES, from 2010 to 2015, was US$27,839.23. However, other costs are involved and the shown estimative goal is to complement the discussion of results, focusing on the WEEE management importance from an environmental and economic point of view.

Besides the sale of PCB, another alternative for the WEEE management would be the partnership with waste pickers associations, focusing on the primary processing of the waste.

TABLE III
ESTIMATE OF THE GROSS VALUE OBTAINED WITH THE SALE OF THE PCBS OF UFES SCRAP COMPUTERS IN THE PERIOD FROM 2010 TO 2016

Period	PCB (estimated amount)	Average weight of PCB (Kg)	Total average weight PCB (Kg)	Average price of PCB/Kg (U$)	Value (U$)
2010-2015	7064	0.7	4,944.8	5.63	27,839.23

2. LCD and CRT Monitors

LCD and CRT monitors were present in high quantities on UFES, with 1810 unities from 2010 to 2015.

Due to the presence of harmful substances, CRT monitors represent a problem regarding its final disposal. The high quantity of CRT monitors on the UFES storage. The commercialization of new technologies such as LCD and LED monitors boosted the waste generation of CRT monitors [26].

The indium is a rare metal, representing only 0.1 ppm of earth's crust [27]. Beyond rare, for being a metal without own minerals, its extraction is hampered. It is commonly found associated with copper, lead and mainly zinc. Therefore, it is obtained as a by-product from metallurgical process. Due to its application on liquid crystal screens and solar cells, the indium has been increasingly exploited.

3. Printers

The sale of printer equipment in 2015 were quantified in 2.5 million unities of machines, earning US$676 million and the commerce of inkjet printer were quantified in 641,6 thousands of unities, moving around US$227 million [28]. In the period from 2010 to 2015, UFES generated 405 printers.

The use of printer cartridges is directly proportional to the sale of printers. The Brazilian Support Service of Micro and Small Enterprises [29] indicates expansion of the cartridge refill market. The annual growth of the sector is 30%, according to SEBRAE. This occurs due to the higher price of new cartridge [29]. According to SEBRAE, the average annual increase of the commercialization of printers presents a value of 20%.

A cartridge could be refilled three times at the most. It is common in Brazil to discard the non-rechargeable cartridge among general solid urban waste [30]. This practice creates serious environmental impacts and needs to be addressed, considering that there is a gap on this product management in Brazil [30].

A problematic associated with the discard without proper management of cartridge is the presence of residual ink.

C. Identification of Alternatives to the WEEE Management on UFES Campuses

The WEEE generation diagnostic on UFES campuses identified the following associated problems:

- Segregation as unique stage of processing;
- Difficulty on collection frequency at Alegre and São Mateus campuses;
- Precarious structure for storing and implementation of systems for primary process of WEEE;
- Necessity of staff training to implementation of primary processing.
- Lack of partnership with waste pickers associations to perform primary processing.

Implementing WEEE management plan would result in the following advantages:

- Strategies of reuse and recycling of WEEE [19];
- Possibility of implementation of classification and characterization activities, relating to triage and segregation. Appropriate segregation facilitates the recycling process, as well as correct disposal of waste, according to Camargo [19];
- Reduction of natural resources extraction, as well as no longer dispose improperly waste, would be positive consequences to the environment, according to [23].
- Inclusion of Waste Pickers associations on primary processing, therefore, adding value to the product [21].

According to the facts, the following text presents alternatives to the implementation of a WEEE management plan on UFES campuses.

Implementation of RL, according to Brazilian National Solid Waste Policy [31], consists of returning the waste to the business sector, both for reuse and/or proper final disposal. For the implementation of RL, a participation of various actors is mandatory. Therefore, generators, public power, fabricants and importers would fit the concept of shared responsibility [32].

Higher Education Institutions through their activities generate different kinds of waste [33]. The different kinds of waste characterize a complex and heterogeneous matrix, with several negative impacts on the environment if managed improperly. The greater challenge to be addressed, rather than technological and legal aspects, is in the ethical dimension, the social responsibility, attached to a continuous educative process [33].

During the research, the majority of the employees from the patrimonial sector of UFES presented a lack of knowledge over RL. However, some employees were able to undertake online classes about the Nacional Solid Waste Policy, during the period of the research. Although, for a proper implementation of the reverse logistic, it is necessary improve the WEEE management by triage and segregation. Another obstacle is that, according to the University law, only donation and auctions are allowed as destination of the waste. Creating a triage center specifically for WEEE, including the waste pickers association could be an efficient alternative.

The first goal of the triage is to evaluate if the electronical equipment can be reused. If verified able to use, it would go through a repairing process and then distributed for use on campus. The electronic equipment, characterized as WEEE, should go through a process of separation according to its kind and then according to its characteristics [34]. The University could use the separated WEEE for researches. Waste pickers associations could receive donations of WEEE from the University. The WEEE classified as high benefit could be commercialized or auctioned.

To the sale of printed circuit boards and other high value components, the creation of a primary processing Center of WEEE generated on UFES would be important. Hiring and relocating employees to disassembly and classify the WEEE. In the Center of Disposal and Reuse of Computer Waste (CEDIR), São Paulo University, social programs focusing on capacitation of staff to disassembly WEEE would also be an option. In Brazil, selective collect including waste pickers organizations was incorporated in 2007 by the Federal Law n. 11.445 (Basic Sanitation National Policy), and the Solid Waste National Policy (Federal Law n. 12.305) [31].

There are costs for implementing those alternatives. However, the initial cost of implementation is low, bearing in mind that the triage is a manual process. The infrastructure investment consists of workstations with tools and utensils to dismantling and segregating, and availability of a triage and temporary storage area, including a protected temporary storage area to waste cartridges due to potential ink leakage contamination. For this purpose, the creation of storage niches for each type of waste would be efficient. Despite the implementation cost, a primary processing center could be a feasible alternative.

IV. Conclusion

After accomplishing the diagnostic on UFES campuses, the existence of WEEE in great quantities and varieties were noted. WEEE stays, most of the time, stored for donation or auctions, without reuse evaluation

The WEEE storage is disorganized and inadequated. These arrange hampers their management and could damage equipment with reuse potential. That way, the processing and reuse of the WEEE is difficult.

From the data quantification from 2010 to 2015, 17 categories of WEEE were identified. Among them, the data processing equipment presented the greater amount. The coherence of this result is due to the content of this category, which includes computers, printers, keyboards, mouse, etc., applied in different university centers.

Some WEEE such as LCD and CRT monitors and printers had their recycling potential evaluated.

From the estimative relating the quantity of PCBs from computers identified from 2010 to 2015, it was found that the primary processing followed by their sale would earn approximately R$141.280,00. This result could be used as a motivation to the implementation of this kind of process on UFES campuses.

CRT monitors are the most numerous, with 1853 unities among the identified WEEEs. The presence of lead is an environmental issue related to their final disposal. LCD monitors present indium in their composition, which is a rare valuable metal, justifying the recycling study for this WEEE.

Printers are counted with 402 unities from 2010 to 2015. This WEEE is associated to the use of inkjet printer cartridges. The high generation of this waste is justified by their restricted use by three recharges. Beyond the high generation of secondary waste by the printer, the waste cartridges can be associated with the impact caused by their residual ink in contact with the environment.

Alternatives were presented to the WEEE management implementation on UFES campuses. Therefore, the implementation of reverse logistic was proposed. To fulfil that, the implementation of triage and segregation of WEEE would facilitate their management for future reuse and recycling through reverse logistic. Associated with the reverse logistic, the inclusion of waste pickers association in the process of triage and segregation would boost the production efficiently.

Lastly, it is necessary to inform and capacitate the staff that manages the WEEE.

Acknowledgment

The authors wish to thank the Fundação de Amparo à Pesquisa e Inovação do Espírito santo (FAPES), Brazil for research financial (Process n°68781369/2014).

References

[1] D. Hoornweg and P. Bhada-Tata. What a waste: A Global Review of Solid Waste Management, 2012, 15. ed. The World Bank, Washington, United States.

[2] IBGE – Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics). População do Brasil (Population of Brazil.) Accessed on: 18 August 2016. Available at: <http://www.ibge.gov.br/apps/populacao/projecao/>.

[3] ABRELPE - Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais (Brazilian Association of Public Cleaning and Special Waste Companies). Panorama dos Resíduos Sólidos no Brasil 2014 (Overview of Solid Waste in Brazil 2014). Brazil, São Paulo, 2014.

[4] Riitta, Pipatti et al. Waste Generation, Composition and Management Data. In: Japan. Institute for Global Environmental Strategies. (Org.). 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Waste. Hayama, 2006. p. 1-23.

[5] P. R. Jacobi and G. R. Besen. Gestão de resíduos sólidos na região metropolitana de São Paulo (Solid waste management in the metropolitan region of São Paulo). São Paulo em Perspectiva (São Paulo in Perspective), 2006, v.20, n.2, p. 90-104.

[6] ABDI - Agência Brasileira de Desenvolvimento Industrial (Brazilian Industrial Development Agency). Logística Reversa de Equipamentos Eletroeletrônicos (Reverse Logistics of Electrical and Electronic Equipments). Brazil, Brasília, November, 2013.

[7] D. Maccan and A. Wittman. Solving the E-Waste Problem (Step) Green Paper, 2015, E-waste Prevention, Take-back System Design and Policy Approa-ches. Accessed on 18 August 2016. Available at: <http://www.step-initiative.org>.

[8] C. P. Baldé, F. Wang, R. Kuehr and J. Huisman. The global e-waste monitor – 2014. United Nations University, IAS-SCYCLE, 2015, Bonn, Germany.

[9] S. Sthannopkao and M.H. Wong Handling e-waste in developed and developing countries: Initiatives, practices, and consequences. Science of the Total Environment, 2012, vol. 463-464. p. 1147-1153.

[10] A. C. Rodrigues. Fluxo domiciliar de geração e destinação de resíduos de equipamentos elétricos e eletrônicos no município de São Paulo/SP: caracterização e subsídios para políticas públicas (Household flow of generation and destination of waste of electrical and electronic equipment in the city of São Paulo/SP: characterization and subsidies for public policies). Doctoral Thesis. Sciences Department, University of São Paulo, Brazil, 2012, 246p.

[11] B. H. Robinson E-waste: An assessment of global production and environmental impacts. Science of the Total Environment, 2009, vol. 408. n. 2 p. 183-191.

[12] Z.H.I. Sun, Y. Xiao, J. Sietsma, H. Agterhuis, G. Visser and Y. Yang Characterization of metals in the electronic waste of complex mixtures of end-of-life ICT products for development of cleaner recovery technology. Waste Management., 2015, Vol.35, p. 227-235.

[13] M. Schluep, C. Hagelueken and R. Kuerh. Solving the E-waste Problem (Steep), 2009, Recycling - From E-waste to Resources. Access on 18 August 2016. Available at: < http://www.unep.org/pdf/Recycling_From_e-waste_to_resources.pdf >.

[14] Y. N. Park and FRAY, D. J. Fray Recovery of high purity precious metals from printed circuit boards. Journal of Hazardous Materials, 2009, vol.164, p. 1152-1158.

[15] H. M. Veit. Reciclagem de Cobre de Sucatas de Placas de Circuito Impresso (Recycling Copper Scrap Printed Circuit Boards). Doctoral thesis. Department of Mines, Metallurgical and Materials Engineering, Federal University of Rio Grande do Sul, Brazil, 2005, 101p.

[16] H. M. Veit and A. M. Bernardes Chapter 2: Electronic Waste: Generation and Management, 2015, p. 3-12. In: Bergmann, C. P. (org) Electronic Waste: Recycling Techniques. Porto Alegre: Springer.

[17] J. Demajorovic, E.E.F. Augusto and M.T.S. Souza Logística reversa de REEE em países em desenvolvimento: desafios e perspectivas para o modelo brasileiro (Reverse Logistics of WEEE in developing countries: challenges and perspectives for the Brazilian mode). Ambiente & Sociedade (Environment & Society). 2016, v. XIX, n.2. p. 119-138.

[18] A. C Rodrigues, W. M. R. Gunther and M. E. Boscov. G. Estimativa da geração de resíduos de equipamentos elétricos e eletrônicos de ordem domiciliar: proposição de método e aplicação ao município de São Paulo, São Paulo, Brasil (Estimation of the generation of waste electrical and electronic equipment of household order: proposal of method and application to the city of São Paulo, São Paulo, Brazi). Engenharia Sanitária Ambiental (Environmental Health Engineering), 2015, v.20, n.3 p. 437-447.

[19] I. G. N. Camargo. Diagnóstico da gestão e do gerenciamento dos resíduos eletroeletrônicos gerados no campus da faculdade de engenharia de Guaratinguetá/UNESP (Diagnosis of the management and management of electro-electronic waste generated at the Guaratinguetá/UNESP engineering college campus). 2013, Trabalho de conclusão de curso, Departamento de Engenharia Civil, Universidade Estadual Paulista, Guarantiguetá. 81 p.

[20] Pró-reitoria de Planejamento e Desenvolvimento Institucional (Pre-Rectory of Planning and Institutional Development). UFES Indicadores de Desempenho – 2015 (UFES Performance Indicators - 2015). Brazil, Vitória, 2015.

[21] G.H.T. Rocha, F.V.B. Gomes, M.S. Porte, S. M. Portugal R.N. and J.C.J. Ribeiro; Diagnóstico de Geração de Resíduos Eletroeletrônicos no Estado de Minas Gerais, (Diagnosis of Generation of Electrical and Electronic Waste in the State of Minas Gerais). 2009, 85 p.

[22] R. T. G. Andrade, C. S. M. Fonseca and K. M. C. Mattos. Geração e destino dos resíduos eletrônicos de informática nas instituições de ensino superior de Natal-RN (Generation and destination of waste in the higher education institutions of Natal-RN). Holos, 2010, v.2, p. 100-112.

[23] F.C. Miranda, P.V. Brandão, C.P. Souza, M.M. Velosso and F.R. Leta. Gerenciamento de resíduos - uma análise econômica do potencial de reciclagem de computadores, considerando o caso da Universidade Federal Fluminense – UFF (Waste management - an economic analysis of the recycling potential of computers, considering the case of Federal Fluminense University – UFF), 2013, Paper presented in VII CIBEM – Congresso Iberoamericano de Educação Matemática (Ibero-American Congress on Mathematical Education).

[24] A. E. Gerbase and C. R. Oliveira Reciclagem do lixo de informática: uma oportunidade para a química (Recycling of e-waste: an opportunity for chemistry). Química Nova (New Chemistry), 2012, vol.35, n.7, p. 1486-1492.

[25] R.G.F. Franco & L.C. Lange. Estimativa do fluxo dos resíduos de equipamentos elétricos e eletrônicos no município de Belo Horizonte, Minas Gerais, Brasil (Estimator of the disposal of waste electrical and electronic equipment in the city of Belo Horizonte, Minas Gerais, Brazil). Eng. Sanit. Ambient, 2011, v.16, n.1, p. 73-82.

[26] E. L. B. O. Oliveira, G. Feron and H. M. Veit. Leaching of cathode ray tube as a justification for recycling. Proceedings of the 3rd International Congress on Technologies for the Environment, 2012, p. 6.

[27] Hashimoto Estudo da extração de indium a partir de telas de cristal líquido (LCD) (Study of the extraction of indium from liquid crystal screens (LCD)). Masters Dissertation. Department of Chemical Engineering, Politechnical School of University of São Paulo, Brazil, 2015, 106 p.

[28] IDC Brasil (IDC Brazil). Pesquisa da IDC Brasil revela que o mercado de impressão apresentou queda no primeiro semestre de 2015 (Research from IDC Brazil reveals that the printing market presented a drop in the first half of 2015). Access on 19 August, 2016. Available at: <http://br.idclatin.com/releases/news.aspx?id=1928>.

[29] SEBRAE/ES - Serviço Brasileiro de Apoio às Micro e Pequenas Empresas do Espírito Santo (Brazilian Service of Support to Micro and Small Companies of Espírito Santo). Empresa de remanufatura de cartucho (Cartridge remanufacturing company). UCA – Unidade de Captação de Recursos & Atendimento (Fundraising & Service Unit), 2008, p. 10.

[30] F. P. Moura, R. S. Oliveira, J. C. Afonso, C. A Vianna and J. L. Mantovano. Processamento de cartuchos de impressora de jato de tinta: um exemplo de gestão pós-consumo (Inkjet printer cartridges processing: an example of post-consumer management). Química Nova (New Chemistry), 2012, vol. 35, n.7, p. 1271-1275.
[31] BRAZIL. Law nº 12.305, 2 August 2010. Institui a Política Nacional de Resíduos Sólidos (Institutes the National Solid Waste Policy).
[32] J. Fernandes, A. Moura and J. C. Roma Sistema de logística reversa: responsabilidade compartilhada sobre o ciclo de vida do produto (Reverse logistics system: shared responsibility over the product life cycle). Vol. 74. 2012. Access on 18 August 2016. Available at: <http://www.ipea.gov.br/desafios/index.php?option=com_content&view=article&id=2835:catid=28&Itemid=23>.
[33] L. B.Corrêa, V. L. Lunardi, P. R. Jacobi Educação ambiental na construção de políticas para a gestão dos resíduos em uma instituição de ensino superior (Environmental education in the construction of policies for waste management in an institution of higher education). Revista Brasileira de Educação Ambiental (Brazilian Journal of Environmental Education), 2012, v.7, p.9-15.
[34] T.C.M.B. Carvalho, A. Falciano; I. Margarido, L. Martins; S. Moraes, E. Bonilha, N. Bicov, R. Mitie; L. Sonnewend and M. Bernardes Tratamento Sustentáveis de Lixo Eletrônico (Sustainable Treatment of E-waste). Presented at the Mario Covas Prize, 2009, 38p.
[35] G. R. Besen, H. Ribeiro, W. M. R. Gunter and P. R. Jacobi. Coleta seletiva na região metropolitana de São Paulo: impactos da Política Nacional de Resíduos Sólidos (Selective collection in the metropolitan region of São Paulo: impacts of the National Solid Waste Policy). Ambiente & Sociedade (Environment & Society), 2014, v. XVII, n.3. p. 259-278.