UNIVERSIDADE DE SÃO PAULO
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The recycling of electronic waste:
Regulations and corporate strategies in Brazil and in Europe

São Paulo
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To my mother and my brother, my safe port no matter where we are.

In memoriam of my grandfather Arnyldo Borba Frantz,
who always defended education as one of the most important values in life.

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“Nothing is impossible, particularly if it is inevitable”.

(Herman Mulder apud ELLEN MACARTHUR FOUNDATION, 2012, p. 84)

RESUMO

Com o extremo crescimento de resíduos eletrônicos ao redor do mundo e no Brasil, há uma enorme necessidade de aprimoramento dos processos de reciclagem para tal tipo de resíduo. Considerando o tema de extrema relevância, o objetivo geral da presente pesquisa é o de estudar a respeito das regulamentações e estratégias corporativas em relação à reciclagem de resíduos eletrônicos no Brasil e compará-las com o contexto europeu. Os objetivos específicos são: Analisar em termos gerais o cenário europeu a respeito de sustentabilidade e de resíduo eletrônico, a fim de compará-lo com o cenário brasileiro; estudar as principais regulamentações no que tange ao tratamento de resíduos eletrônicos na Europa e no Brasil; identificar os principais atores envolvidos no processo de reciclagem de eletrônicos no Brasil; analisar como alguns dos principais fabricantes de eletrônicos informam em seus websites sobre ações para reciclagem de eletrônicos no Brasil e na Europa; e estudar como alguns dos principais fabricantes de eletrônicos no Brasil lidam com a questão da reciclagem de eletrônicos tanto sob o ponto de vista estratégico como operacional. Com uma natureza qualitativa, a pesquisa tem diferentes abordagens em termos de metodologia. Tanto a parte do cenário europeu como a parte de aspectos institucionais e legais no Brasil são baseadas em dados secundários. A parte dos estudos de caso traz uma análise sobre os websites no Brasil e no Reino Unido de algumas fabricantes de eletrônicos, resultados do contato com o serviço de atendimento ao consumidor de tais empresas no Brasil e uma parte final com entrevistas com duas das empresas, um parceiro de reciclagem de uma das empresas e uma associação de reciclagem de eletrônicos. Entre os principais programas da Comissão Europeia identificados para um crescimento sustentável, há a *Estratégia Europa 2020* e o *7° EAP*. Enquanto a União Europeia tem as Diretivas WEEE e RoHS em termos de legislação, o Brasil conta com a Política Nacional de Resíduos Sólidos (PNRS). A maioria das empresas analisadas não tem um link direto para obter informações sobre o descarte em suas homepages no Brasil, enquanto que outras não têm qualquer informação sobre o assunto. Ao contatar o serviço de apoio ao cliente, algumas empresas forneceram informações divergentes dos websites. Constatou-se que muitas empresas não estão com ações adequadas à reciclagem de eletrônicos no Brasil, além de não estarem lidando com o resíduo de maneira estratégica. As empresas do Reino Unido têm, em geral, ações melhores que as do Brasil, com a maioria das empresas tendo diferentes ações de acordo com o país. Entre as principais incertezas identificadas na reciclagem de eletrônicos, destacam-se: Diferentes tecnologias de reciclagem; impactos ambientais desconhecidos; design e composição de produto variados; custo desconhecido de logística reversa; custo variável de

reciclagem; natureza rapidamente mutável dos equipamentos eletrônicos; imprevisibilidade de retorno dos itens em relação à quantidade, à qualidade e ao tempo; destino desconhecido dos resíduos; valores distintos de materiais de sucata; falta de legislação comum; complexidade de regulamentações; falta de consciência ambiental; e falta de classificação e regulamentação dos resíduos na PNRS.

Palavras-chave: Economia circular. Economia verde. Desenvolvimento sustentável. Resíduo eletrônico. Logística reversa. Estratégia. Incertezas. Reciclagem.

ABSTRACT

With the extreme growth of electronic waste worldwide and in Brazil, there is a huge need for enhancement of recycling processes for this sort of waste. Considering the extremely relevant topic, the main objective of this research is to study about regulations and corporate strategies towards electronic waste recycling in Brazil and to compare it with the European context. The specific objectives are: To analyse the general European scenario concerning sustainability and electronic waste, in order to compare it with the Brazilian scenario; to study the main regulations for the treatment of electronic waste in Europe and in Brazil; to identify the main actors involved in the recycling process of electronics in Brazil; to analyse how some of the main electronics' manufacturers inform on their websites about actions towards recycling of electronics in Brazil and in Europe; and to study about how some of the main electronics' manufacturers in Brazil are dealing with the recycling of electronics from both a strategic and operational point of view. With a qualitative nature, the research has different approaches in terms of methodology. Both the part of the European scenario and the part of institutional and legal aspects in Brazil are based on secondary data. The part of the case studies brings an analysis on the websites in Brazil and in the United Kingdom of some electronics' manufacturers, results from the contact with their customer services in Brazil and a final part of interviews with two of these companies, one of these companies' recycling partner and a recycling association of electronics. Among the main programmes from the European Commission identified towards a sustainable growth, there is *The Europe 2020 Strategy* and the *7th EAP*. While the European Union has the WEEE and RoHS Directive in terms of legislation, Brazil relies on the National Solid Waste Policy (PNRS). Most of the companies analysed do not have a direct link for information about discard on their homepages in Brazil, while some do not have any information on the matter. By contacting the customer service support, some companies have provided divergent information from the websites. It has been possible to observe that many companies do not have proper actions towards the recycling of electronics in Brazil, in addition to not dealing with the residue in a strategic manner. The companies in the United Kingdom have, in general, better actions than the ones in Brazil, with most of the same companies having different actions according to the country. Among the main uncertainties identified in the recycling of electronics, there are: Different recycling technologies; unknown environmental impacts; different product design and composition; unknown reverse logistics costs; variable cost of recycling; rapidly changing nature of electronics; unpredictability about return of items concerning quantity, quality and timing;

unknown destination of WEEE; different value of scrap materials; lack of common legislation; complexity of regulations; lack of environmental consciousness and lack of residues' classification and regulations on the PNRS.

Keywords: Circular economy. Green economy. Sustainable development. Electronic waste. Reverse logistics. Strategy. Uncertainties. Recycling.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABDI	*Agência Brasileira de Desenvolvimento Industrial* (Brazilian Agency of Industrial Development)
ABINEE	*Associação Brasileira da Indústria Elétrica e Eletrônica* (Brazilian Electrical and Electronics Industry Association)
ABNT	*Associação Brasileira de Normas Técnicas* (Brazilian Association of Technical Standards)
ABREE	*Associação Brasileira de Reciclagem de Eletroeletrônicos e Eletrodomésticos* (Brazilian Association for Electronics and Home Appliances Recycling)
CAPES	*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (Coordination for the Improvement of Higher Education Personnel)
CEMPRE	*Compromisso Empresarial para Reciclagem* (Business Commitment for Recycling)
EAP	Environment Action Programme
EEA	European Economic Area
EEE	Electrical and Electronic Equipment
ELETROS	*Associação Nacional de Fabricantes de Produtos Eletroeletrônicos* (National Association of Electronic Products' Manufacturers)
EoL	End-of-life product
EPA	Environmental Protection Agency
ERP	European Recycling Platform
EU	European Union
GNP	Gross National Product
IT	Information Technology
PNRS	*Política Nacional de Resíduos Sólidos* (National Solid Waste Policy)
RoHS	Directive on the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment
SSCM	Sustainable Supply Chain Management
UNEP	United Nations Environment Programme
USP	*Universidade de São Paulo* (University of São Paulo)
WCED	World Commission on Environment and Development
WEEE	Waste Electrical & Electronic Equipment

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1 INTRODUCTION

For a long time, especially after the 2nd Industrial Revolution, the patterns of consumption began to be based on extremely high rates, a trend that has been growing throughout the years. Nevertheless, this exaggerate consumption without a proper disposal has many negative effects that are becoming more evident every passing day.

Technological advances have made the consumption of electronics grow in a fast scale. As a result, those products' life cycle has been falling in the same proportion and today represents a worldwide trend. Products that used to last for a long time and were hardly disposed of are now renewed within a remarkable short time.

The discarded products, called electronic waste or Waste Electrical and Electronic Equipment (WEEE), can be recycled and have high value due to the presence of precious materials. Nevertheless, they have a number of peculiarities that makes the collection and recycling process complex and costly. One of the main problems for this process is the difficult removal of the precious materials in a safe and environmentally friendly way, which demands advanced technology. Another point to consider is that this high complexity involves various actors in the process, which demands a coordinated approach in order for the process to be effective.

As a result, the electronics are most frequently discarded in an inappropriate manner. They have elements in their composition that cause serious risks to the population if not discarded properly (THE WORLD BANK, 2012). These elements also have a strong impact on the environment and, thus, a proper management for this material represents a direct benefit for the planet's sustainability.

In the scenario of the newly industrialized countries, Brazil is among the countries that generate the highest rates of electronic waste. In the global scenario, Brazil has the fifth biggest global electronic and IT market (THE WORLD BANK, 2012). Therefore, the Brazilian scenario is a very interesting case to be studied further, not only among the emerging markets, but also in the global sphere.

With the growing resource scarcity, the concept of sustainable development gets stronger every day. According to the United Nations Industrial Development Organization (UNIDO), a sustainable industrial development is one of the new global challenges for obtaining a sustainable development. In this sense, they have coined the concept *green industry* as an economy that includes resource efficient and cleaner productivity, policy making and improved industrial production processes in order to achieve a sustainable growth. In what a

resource efficient and cleaner productivity is concerned, it means minimizing the generation of emissions and waste, besides fostering a responsible production, by using preventive management strategies in the use of natural resources.

The recycling process of electronic waste represents today a huge environmental problem, but it can be turned into a profitable investment. With enough knowledge and willingness to make a change, this is possible. Taking into account the lack of structure to meet this strong market growth and the need of more sustainable approaches towards the subject, a more detailed study about it is of extreme importance. Therefore, studying the present scenario of electronic waste recycling could bring insights for new approaches to be taken from all different actors involved in the process: from governmental policies to companies' practices.

1.1 Research question

With the extreme growth of electronic waste worldwide and in Brazil, there is a huge need for enhancement of electronic waste recycling processes. Although multidisciplinary, this subject is directly linked with Production Engineering, as its body of knowledge contains corporate strategies, processes and sustainability. Especially when taking into account the scarce resources and their importance in the production, the need of environmentally friendly production systems are of growing importance.

Taking this into consideration, the research question of the present study has been elaborated as the following: *How is the current scenario of electronic waste recycling in Brazil and in Europe concerning regulations and corporate strategies?*

1.2 Research objectives

In line with the research question and the literature review on the subject, the main objective of the research is summarized as: *To study about regulations and corporate strategies towards electronic waste recycling in Brazil and to compare it with the European context*.

From the main objective, it is possible to break it down into the following specific objectives:

a) To analyse the general European scenario concerning sustainability and electronic waste, in order to compare it with the Brazilian scenario;
b) To study the main regulations for the treatment of electronic waste in Europe and in Brazil;

c) To identify the main actors involved in the recycling process of electronics in Brazil;
d) To analyse how some of the main electronics' manufacturers inform on their websites about actions towards recycling of electronics in Brazil and in Europe;
e) To study about how some of the main electronics' manufacturers in Brazil are dealing with the recycling of electronics from both a strategic and operational point of view.

1.3 Research structure

The current work is divided into seven chapters. In addition to the complementary chapters, the research has four main parts, which are illustrated in *Figure 1*. Chapter 1 brings an introduction of the subject, with a broad justification for the research, defining the research question and objectives, in addition to presenting the research structure. Chapter 2 specifies the methodology applied for the research that is presented on chapters 3, 4, 5 and 6.

In line with the research question and objectives, chapter 3 brings the literature review of the following subjects: Green economy and sustainable development; circular economy; electronic devices and electronic waste; reverse logistics of electronic waste; strategy for the reverse logistics and recycling of electronics; and innovation and uncertainties in the recycling of electronics. There is a final section for discussion in the end of the chapter. After this review, it is possible to continue with further studies.

Chapter 4 deals with the European scenario, so that to have a tool for comparison with the Brazilian framework. To have a broad view on the subject, it first highlights some of the main programmes put into practice by the European Commission concerning a sustainable growth and a sustainable development. Later on, it deals specifically with the subject of electronic waste in the European context, bringing the current situation in Europe and the European legislations towards the subject. The final section is the discussion of the chapter.

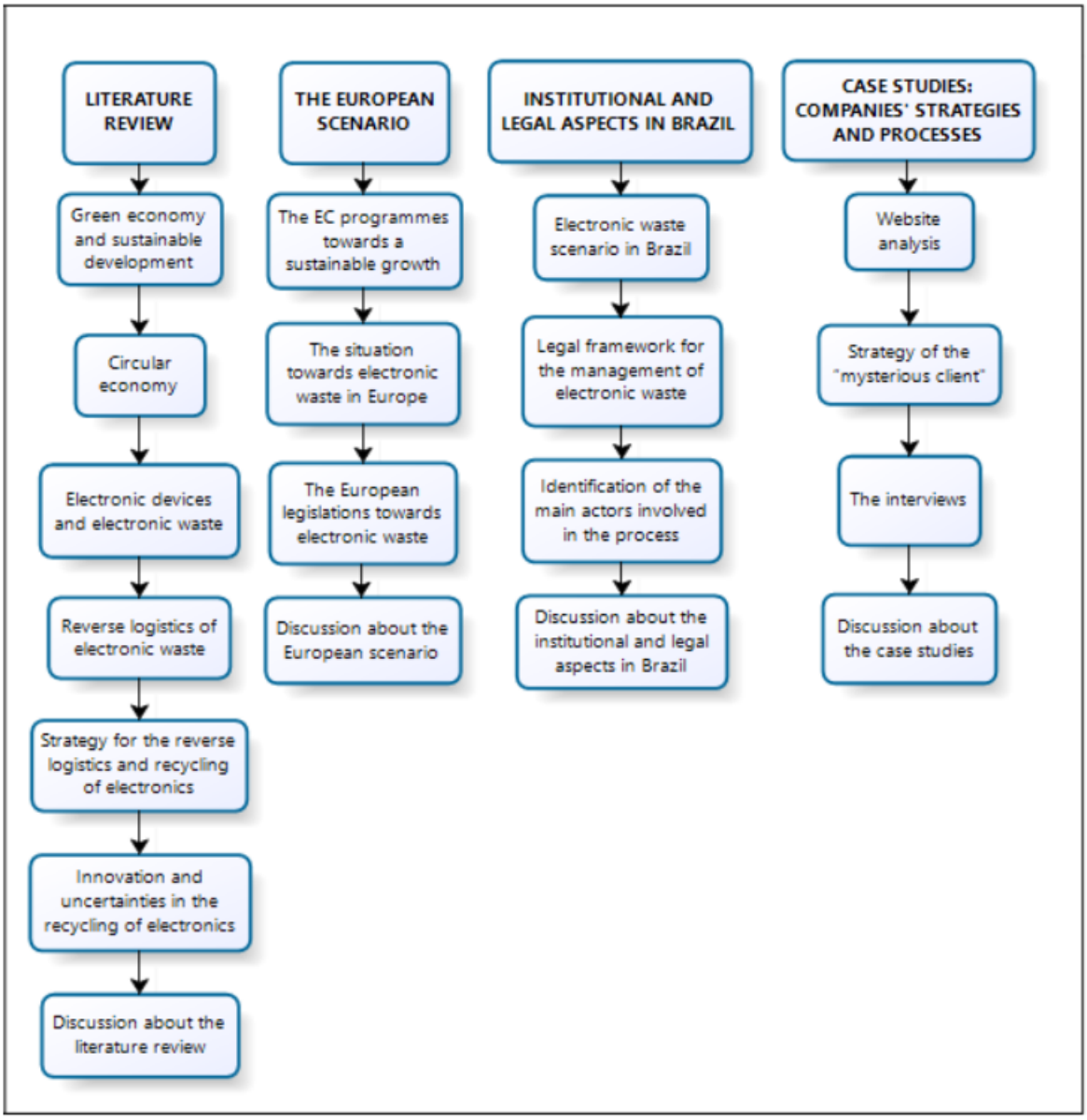
Chapter 5 brings the institutional and legal aspects for the management of electronic waste in Brazil. Based on a secondary data analysis, it first presents the electronic waste scenario in Brazil and then studies the legal framework for the management of electronic waste in the country. Afterwards, it identifies some of the main actors involved in the process and also has a section for discussion.

The case studies are presented on the next chapter, the sixth. The first part presents the analysis conducted on the websites of the main notebook manufacturers in Brazil, besides a comparison with their websites in Europe. The second part brings the strategy of the *mysterious*

client, in which the researcher has contacted the customer service area of such companies in Brazil, pretending to be a client. The third part brings the results of the interviews conducted with two notebook manufacturers, one recycling company and one recycling association. The last part is a space for discussion about the chapter.

Chapter 7 brings the final considerations of the research. It highlights some limitations of the current work and gives suggestions for further research.

Figure 1 - Research structure



Source: Developed by the author

2 METHODOLOGY

The main purpose of any research is to produce insights or knowledge and, as such, it is based on the knowledge already existent on the subject, with the aim of creating new insights on it. In order to be original, the topic of research does not have to be entirely different from the researches already done, but it needs to create a new dimension to the already existing knowledge. In order to achieve that, the research works as a process, taking time and consideration, being modified over time and having different stages, each one with different tasks (GHAURI, 2010).

According to Ghauri (2010), each research involves a process that should be based on systematic procedures and approaches of advancing knowledge that may also serve for managerial problem solving. Further, the research orientation depends on its relation between the methods, data, theories and values.

The methodology of research is a set of procedures and methods that aims at collecting, systematizing and organizing data in a consistent manner, in such a way to allow a scientific interpretation. As such, it is part of a process full of trials, experiments, errors and successes (MIGUELES, 2004).

Considering the subject not very well structured in the literature, the present research has an exploratory nature, according to the objective and extent to which the research is defined. An exploratory research is not much or even not structured at all in terms of procedures and its objectives are not well defined, with the aim of developing new theoretical and empirical insights about the topic, which is still incipient within the academic sphere. It aims to gather further knowledge about a specific topic and to develop hypotheses for future studies (MALHOTRA, 2004).

In terms of its nature, the present research is classified as a qualitative research. According to Malhotra (2004), the difference between a qualitative and a quantitative research is similar to the difference between a conclusive and an exploratory research. While the main objective of the quantitative research is to quantify the data, the qualitative research aims at a better comprehension of the reasons and motivations for a specific subject. Therefore, while the quantitative research has a larger number of representative cases, the qualitative research focus on fewer cases, so that to study them more deeply.

Gephart (2004) further explains that a qualitative research usually emphasizes qualities of entities, studying phenomena in the environments in which they naturally occur and using social actors' meanings to understand the phenomena. It is often designed at the time it is being

done and requires highly contextualized individual judgments, offering different views of realities that cannot be reduced to few variables. Furthermore, a qualitative research is interpretive and inductive, having a literary and a humanistic focus, with the important value of describing and understanding the actual human interactions, processes and meanings of a specific subject.

The qualitative research has the purpose of understanding reasons and motivations about a specific subject, providing insights into the setting of a problem in order to generate ideas for later quantitative research, or uncovering prevalent trends in thought and opinion. It usually has a small number of non-representative cases, the data collection occurs under unstructured or semi-structured techniques and the data analysis is non-statistical. The findings cannot be used to generalize to the population of interest, but to develop an initial understanding for further decision making.

One of the main features of the qualitative approach is to provide insights that are difficult to produce with a quantitative research. It may, for example, result in bases for understanding social processes, examples of important issues and concepts that enrich the field and highlight the human interactions and meanings of a specific phenomenon (GEPHART, 2004).

According to what has been described in the section *Research structure*, the work is divided in four main parts: the literature review; the European scenario; the institutional and legal aspects for the management of electronic waste in Brazil; and the case studies. According to Gephart (2004), qualitative data may be collected using one or more research approaches, such as studies, interviews, observations, grounded theory, and textual analyses. For the present research, different approaches have been applied so to have a more holistic view on the subject.

The literature review is divided in six main topics, to which different strategies have been taken. For the topic *Green economy and sustainable development* and the topic *Circular economy,* the research is based both on articles and reports that highlight each subject. For the next topics, which are *Electronic devices and electronic waste, Reverse logistics of electronic waste,* and *Strategy for the reverse logistics and recycling of electronics*, the research is based mainly on articles and books. Concerning the topic *Innovation and uncertainties in the recycling of electronics*, it concerns a systematic literature review of the main uncertainties identified on the electronic waste recycling business, based on a search on the *Web of Science* platform. This last topic has been transformed into a paper and was presented at the *International Conference on Science, Technology, Engineering and Management* held in Paris

(France) on 8 March 2015. Afterwards, it was published in the *International Journal of Mechanical and Production Engineering*.

The second part is the European scenario, divided in three main topics. This part is based on secondary data, mainly on reports, laws and regulations from the European Commission. The first one is *The European Commission programmes towards a sustainable growth*, bringing some of the main programmes being put into practice nowadays in the European Union, based on reports from the European Commission. Afterwards, the next two topics work specifically on the electronic waste subject. *The situation towards electronic waste in Europe* shows the current scenario, especially in terms of statistics, while *The European legislations towards electronic waste* highlights the main laws and regulations on the matter.

The institutional and legal aspects for the management of electronic waste in Brazil is the third part of the research. This part brings the analysis of the main regulations for the management of electronic waste in Brazil. Also based on secondary data, mainly laws and reports, it has the main goals of studying about the legal Brazilian framework and identifying the main actors involved in the recycling process of electronics.

The last part of the research brings the case studies and is divided in three main topics. The first topic consists of a website analysis of the ten major notebook manufacturers in Brazil, according to Tecnoblog (2015). It has the main goal of identifying whether and what kind of actions towards recycling these companies have announced on their websites. Besides, it is also analysed how they communicate their activities to the public on their websites. Considering that eight of the ten companies are present worldwide, this topic also analyses the websites of these eight companies in the United Kingdom, comparing the information given by the same companies in the countries of Brazil and the United Kingdom.

The second topic of the case studies consists on the contact with the companies' customer service in Brazil by telephone, in order to analyse how the companies inform the public on how to discard the electronic device produced by them at the end-of-life. For this part, the approach of the *mysterious client* has been taken. As stated by Veal (2011), this method occurs when the researcher participates in the environment of study. Thereby, the researcher has pretended to be a customer looking to discard its electronic device when contacting the customer service in Brazil, demanding the company how to proceed with the discard.

The third topic of the case studies brings the interviews, so that to discover their main practices towards the subject. All the contact has been made either by telephone or e-mail because of financial and territorial reasons. The interviews have been conducted with the Brazilian association for electro-electronics and home appliances recycling (ABREE), two

companies from the list and one recycling partner for another company from the list of the ten major notebook manufacturers in Brazil.

Appendix A brings the model for the introduction letter used for the contact with ABREE and the companies in the original version, which is translated in *Appendix B*. The questions in Portuguese used for ABREE are in *Appendix C* and in English in *Appendix D*. For both the manufacturing and the recycling companies, the model of questions is the same, presented in *Appendix E* in the original version and in *Appendix F* in English.

Taking into consideration that the goal is not to analyse one company only, but to understand the current scenario in some of the companies in Brazil, all companies are analysed in a way to not identifying them individually. The interviews are conducted in a way to gather as much information as possible to analyse how the companies act towards the subject of recycling from both a strategic and operational point of view. The main questions analysed on each case are:

- What kind of actions the company has for the management of their electronic waste;
- Whether they work with other institutions as an outsourced service or on their own;
- In the case they have an outsourced service for the recycling of electronic waste, if they consider to implant the process on their own in the future and why;
- Whether they believe the complete process of recycling of electronic waste may be a profitable business in Brazil;
- What they believe could be improved about the PNRS;
- What they believe are the main uncertainties in the process of recycling of electronic waste;
- Whether the company has any tools for communicating and informing the public about a proper disposal of the electronic waste;
- What kind of sustainability policies the company has.

The research was partly conducted during a Master course in Planning and Sustainability Engineering done by the author at the Polytechnic Engineering School of the University of Tours, during the academic year 2014-2015. For this reason, some parts of the current research are the result of parts of the work done in France. The parts that have been gathered and adapted are the following: *Green economy and sustainable development*; *Circular economy*; *The European scenario*; and *Institutional and legal aspects for the management of electronic waste in Brazil*.

3 LITERATURE REVIEW

The current chapter brings the literature review concerning six main subjects. Firstly, it is studied the concept of green economy and sustainable development. Secondly, the circular economy is analysed, bringing some insights from the Ellen MacArthur Foundation. The electronic devices and electronic waste are studied next, bringing the definition and composition of electronic devices and discussing some of the environmental impacts and the recycling process of the electronic waste.

The reverse logistics of electronic waste is dealt further, as it is directly linked with the process for further recycling. The strategy for the reverse logistics and recycling of electronics is the next subject, highlighting some of the main scholars in the field of strategy, with focus on Porter. The sixth subject talks about innovation and uncertainties in the recycling of electronics, with a systematic literature review on the topic. Finally, the last section of the literature review brings some discussion about the chapter, connecting all the subjects from the literature review.

3.1 Green economy and sustainable development

With the growing concern for environmental issues and how the future is going to be like, the idea of a green economy is gaining strength in all different places around the world. The basic idea of green economy is that it is possible to attend both the social and the economic needs of people without having to exceed the finite resources from the ecosystems (FIORINO, 2014).

Although it may appear, the concept of green economy is not very new. According to Fiorino (2014), the ideas of a green economy already appeared in the way of thinking in the late 1980's. The concept then emerged for the first time, in the visible form, on the book *Blueprint for a green economy*, in 1989 (MCCORMICK; LUTH RICHTER; PANTZAR, 2015).

In order to achieve a more sustainable economy, the *Blueprint for a green economy* book defends that it is necessary to have an improvement in three policy areas. The first one presented by Pearce, Markandya and Barbier (1989) is to value the environment. According to the authors, improvements in the environment usually bring direct or indirect effects in other key areas for the economy, which may be measured in monetary terms. The second policy suggested is accounting for the environment, to which a physical or a monetary approach may be applied.

Lastly, the importance of proper pricing of products and services is mentioned, besides the incentives and penalties that may be applied for obtaining environmental improvement.

One of the most important highlights of the book was the innovative link, at the time, between environment and economy (FIORINO, 2014). The book defends that not only the economy affects the environment, but also the opposite direction is true, as stated already in the first chapter:

> Fundamental to an understanding of sustainable development is the fact that the economy is *not separate from the environment in which we live*. There is an interdependence both because the way we manage the economy impacts on the environment, *and* because environmental quality impacts on the performance of the economy (PEARCE; MARKANDYA; BARBIER, 1989, p. 4).

In this sense, the book defends that the natural environment may and should be perceived as a form of capital asset or, in another words, natural capital. By having an efficient management of this natural capital, it is possible to transform the sustainable development idea into an achievable goal.

Especially today that it is very easily observed the lack of natural resources and its strong impacts on the economic side of production and processes, the interdependence between economy and environment becomes every day clearer. Nevertheless, it is important to take into consideration that, at the time that the book was published, this interdependence was not that evident, neither was such the huge concern towards this subject as it is nowadays.

Although very relevant, the term *green economy* initially was not widely used. It only started to gain strength with the financial crisis of 2008, because of the need of industries and governments to adopt approaches that would both face the recession and work according to environmental protection goals. The book that gave origin to the term in 1989 was then updated for a new version in 2012, called *A New Blueprint for a Green Economy*, written by two of the first book authors (MCCORMICK; LUTH RICHTER; PANTZAR, 2015).

The new version also discusses about the financial crisis, as well as how this event has changed the way of perceiving economic growth:

> [...] the world was confronted over 2008-9 with the worst economic crisis since the Great Depression. There emerged a general perception that these ecological and economic crises need to be tackled simultaneously: an important global policy response to the economic recession was the acknowledgment that measures to reduce carbon dependency and other environmental improvements could have a role in the economic recovery (BARBIER; MARKANDYA, 2012, p.14).

The new version, *A New Blueprint for a Green Economy*, represents an update of the previous book, by mainly discussing what has been achieved in the 20 past years and what the next approaches and actions should be. Concerning global policy challenges, Barbier and Markandya (2012) discuss how there has been a growing concern over ecological scarcity in the past few years and that the knowledge about a direct linkage between environmental degradation/resources use and ecological/climate change is finally more world widespread.

After the financial crisis of 2008, many international organizations started to support the idea of a green economy and focus of how environmental activities could boost economic growth (MCCORMICK; LUTH RICHTER; PANTZAR, 2015). The United Nations Environment Programme (UNEP) was one of them, which still today reinforces this importance in its publications and programmes.

There are some criticisms in relation to the concept of green economy that should be mentioned. The first point is directly linked with the idea of green economy itself. The concept defends "that societies may expand their economies, enhance their competitiveness, increase per capita income and provide jobs, all while remaining within ecological limits" (FIORINO, 2014, p.30), besides reducing poverty and enhancing social equity. Such amazing claims, with apparently no negative points, make many people doubt on its validity.

Another criticism presented by Fiorino (2014) is that the idea is too anthropocentric. Although its goals are worthwhile, some critics say that more than instrumental value, nature's intrinsic qualities are also needed. Another point is that, by measuring benefits, the protection of ecosystems faces a moral point, so that if these benefits cannot be measured, the argument would fail.

Looking with more of a political view, there are criticisms coming both from the left and from the right. The left argues "that the green economy concept serves to legitimize capitalism as managed by liberal democracies and perpetuates the fundamental causes of our ecological crisis" (FIORINO, 2014, p. 30). In other words, for these critics the term green economy has been used as a way to defend business in its normal form.

The right also has criticisms, such as that green economy legitimizes environmentalisms in the sense that more progressive policies in the environmental sphere could be adopted, if green economy was not seeking for continued growth and ecological quality at the same time. Another point mentioned from the right is that it empowers governments, by demanding a more active approach in the society, besides that it may impact political coalitions (FIORINO, 2014).

Nevertheless, it is interesting to clarify that, as stated by UNEP (2011, p.7):

> A green economy does not favour one political perspective over another. It is relevant to all economies, be they state or more market-led. Neither is it a replacement for sustainable development. Rather, it is a way of realising that development at the national, regional and global levels […].

Further, especially about the criticism of empowering governments, it is relevant to have in mind that this empowerment is not mandatory. A green economy, like Fiorino (2014, p.31) points out, "[...] does not necessarily require big government or more bureaucracy. Still, it does involve more in the way of collective action than advocates of limited government care to see".

According to UNEP (2011), although the green economy model can be adopted by different cities worldwide, most of them have fundamentally non-sustainable practices. This is the result of a set of barriers, which vary according to each economic, political and geographic context. They present the main barriers as being fragmented governance, lack of investment, affordability, negative tradeoffs, consumer preferences, vested business interests, switching costs and risk aversion. Concerning fragmented governance, it means the "lack of coordination between policy frameworks that promote green economy measures at supra-national, national, regional and metropolitan levels" (UNEP, 2011, p.473).

Overcoming these barriers is not an easy task. UNEP (2011) states that it requires an approach taken together with the different actors involved, "from governance and planning to incentives and financing" (UNEP, 2011, p. 474).

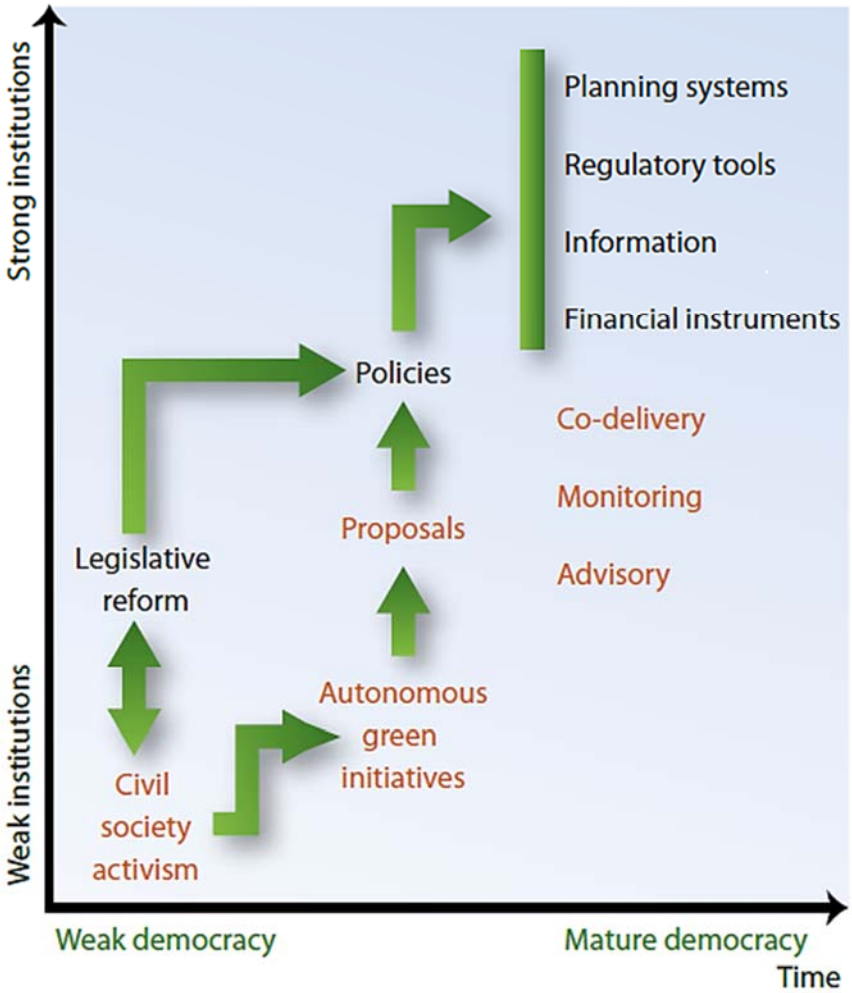
Figure 2 illustrates some of the main policy tools and how they relate in time and with different levels of institutions. It is possible to identify that the changing process from weak to strong institutions is usually a long one, which is closely and directly related to the maturity of democracies. This is the case for initiatives like planning systems, regulatory tools, information and financial instruments. On the other hand, it is possible to see that for some initiatives, like the civil society activism and autonomous green initiatives, it is possible to work effectively in the short and medium term; besides, they do not demand such strong institutions, neither such mature democracies.

Still in relation to *Figure 2,* UNEP (2011, p.474) highlights:

> All of these transition factors suggest that it is critical to develop policy frameworks not just at the local and urban level, but also at the regional and national level. More broadly, policy makers need to look at the conditions that will enable cities in different parts of the world to make the transition to green economy models in relation to the maturity of their own political infrastructure.

They further discuss the importance of governance in a green economy, which "encompasses the formal and informal relationships linking the various institutions involved in the urban system […] and its quality depends on the depth of reciprocity, trust, and legitimacy". (UNEP, 2011, p. 474). Under this perspective, a strong government facilitates the initiatives of planning systems, regulatory tools, information and financial instruments to work in direction to a green economic development.

Figure 2 - Enabling conditions, institutional strength and democratic maturity



Source: UNEP (2011, p.474)

Mccormick, Luth Richter and Pantzar (2015) point out to the fact that there is a variety of concepts related to green economy, like ecological modernization and green jobs. Ecological modernization means that environmentally friendly industries may work in such a way to help avoiding environmental degradation while, at the same time, develop the industrial society.

Another concept related to green economy, which is probably the most notable one, is sustainable development (MCCORMICK; LUTH RICHTER; PANTZAR, 2015). The concept of sustainable development already existed in the 1980's and started to be more widely used after 1987, with the report elaborated by the World Commission on Environment and Development, *Our Common Future*. (BARBIER; MARKANDYA, 2012; FIORINO, 2014). Sustainable development is defined, according to the WCED report (apud BARBIER; MARKANDYA, 2012, p.3) as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Since then, the approach has been developed gradually, both in terms of practical and methodological improvements (HAMDOUCH; ZUINDEAU, 2010b). Nevertheless, the implementation of sustainable development policies is still rather uncertain, especially in strategic and institutional matters. They affirm that one of the main difficulties for this implementation "is due to the need to produce viable institutional changes, which are perceived as being legitimate, durable and efficient" (HAMDOUCH; ZUINDEAU, 2010b, p. 435).

According to Pearce, Markandya and Barbier (1989), the term *development* may be seen, especially from the economic point of view, as *utility* or *wellbeing*. In this sense, the term *sustainable development* may be perceived as *sustainable utility*. From this, it is possible to understand the term *sustainable development* as utility or wellbeing that growths throughout time.

It is interesting to make clear that sustainable economic development is different from sustainable economic growth. A sustainable economic growth is directly linked with the growth of real GNP per capita throughout time, without having negative social or biophysical impacts. On the other hand, a sustainable economic development represents an increase on the per capita utility or on certain development indicators over time (PEARCE; MARKANDYA; BARBIER, 1989).

In order for countries or regions to develop a *green economy*, Hamdouch and Depret (2012) stress a series of common characteristics identified in their country case studies. Among these characteristics, there is a strong political commitment; the use of different tools to address different policies; an engagement of the policies at diverse spatial scales; the efforts in the environmental innovation field over the long-term; an understanding of the need of a high level of involvement among stakeholders on the long run; an *ecosystem* that prioritizes radical environmental innovations; the specialization in one or some sectors in which they may become leaders; and the implementation of incentives and regulations to boost green companies.

It is of utmost importance adopting new approaches with more holistic views, gathering all actors involved. Evidently, such approaches result in a high level of complexity, regarding the diverse objectives and ways of thinking from the different actors involved. Therefore, it is needed not only to gather different actors, but also to change the whole way of designing and implementing the system, in order to ensure that the various objectives from the different actors are taken into consideration.

Equally, Hamdouch and Zuindeau (2010a) make an important enlightenment in relation to the growing and fast technological changes, by pointing out that the implementation of green business can have strong impacts in the economy, increasing its growth and changing models of competition.

When addressing the issue of green economy, Fiorino (2014, p.33) defends that "all nations must redesign policies and institutions to meet human needs in less ecologically stressful ways, although the political hurdles are formidable". Under this scenario, it is also important to consider the human well-being as the main idea for a greener economy.

The process of transition to a green or greener economy is very challenging and there is a lot of complexity involved. It demands a high level of institutional proximity among the different actors involved in order to properly work, which is not an easy process if taken into consideration the different goals and aims of institutions. Nevertheless, it takes into consideration the finite resources, in such a way that it is possible to achieve both economic and social growth without harming the environment. Such goals should be a priority today and in the future, regardless of any political or economic orientation.

3.2 Circular economy

In the traditional view of economic growth, the system is seen as linear. According to the Ellen MacArthur Foundation (2012), one characteristic of this perception is the resource consumption of *take-make-dispose* pattern. This view has spread especially after the 2nd Industrial Revolution and has, as one of its main goals, high rates of production. With the focus only on the production, this view does not worry about the destination of the end-of-life products. Until today, this view is still predominant in the industrial economy.

However, with the increasing lack of natural resources and their high costs involved, improving resource efficiency has been one of the industries main goals for the past years. Still, "any system based on consumption rather than on the restorative use of resources entails

significant losses all along the value chain" (ELLEN MACARTHUR FOUNDATION, 2012, p.14). Therefore, only improving resource efficiency is not enough, if the system still works based on the linear model. While fewer resources are being used for production, the products are yet designed for consumption and discard, with no planning on what is going to be done after their end-of-life.

Besides the linear model not being environmentally sustainable, it also has negative impacts for companies. Especially today, natural resources are becoming scarce with the exaggerated consumption as compared to the planet's limits. Also, just as the urban population increases, so do the costs for extraction, especially due to logistics costs of farther locations.

When analysing environmental issues from a business perspective, these new constraints can be perceived as either a risk or an opportunity. A couple of years ago, environmental management in the business world was usually seen as a risk. Consequently, business tended to be reactive and, in order to address environmental issues, the strategy was mainly by installing end-of-pipe technology that captured pollutants from the industries (HAMDOUCH; DEPRET, 2010, 2012, 2013).

Greyson (2007) makes an interesting comparison between incremental and preventive approaches. In the incremental approach, the problems are treated the way they are perceived, especially in terms of their impacts. On a time when these natural problems were not so evident, this incremental approach seemed even to be successful in some way. On the other hand, with the rise on the number and complexity of world's problems, as well as their interconnection, this approach proved to be insufficient.

By looking only from a financial perspective of production, an incremental approach incurs in both additional costs and resource use for the companies. By contrast, preventive approaches are more difficult to implement, but more promising:

> Preventing impacts is more ambitious than reducing impacts, yet if difficulties with the incremental approach can be avoided then paradoxically a preventive approach may be more manageable and effective. This challenge effectively defines how a preventive approach should work, by addressing underlying systemic problems rather than symptomatic impacts (GREYSON, 2007, p. 1383).

Following the *preventive line* allow companies to directly draw on new business opportunities offered by new technologies and, indirectly, enhance the company's image as it supports a sustainable development approach. As a result, an increasing number of companies

is introducing preventive approaches and looking at the environmental preservation as a business opportunity nowadays (HAMDOUCH; DEPRET, 2010, 2012, 2013).

Because of the need of more sustainable models, different approaches started to gain strength, especially in the last years. There are many strong models dealing with decision-making to achieve a sustainable development, like industrial ecology, performance economy, regenerative design, zero waste, biomimicry, responsible stewardship, blue economy and cradle to cradle. Nevertheless, the circular economy conceptual model may be considered as one of the most powerful (ELLEN MACARTHUR FOUNDATION, 2013; GREEN ALLIANCE, 2011).

The concept of circular economy has many origins and there is no traceability to only one single author or precise date. In 1966, according to Greyson (2007), the great economist Kenneth Boulding coined the term as being the long-term aim gathering sustainability, zero waste and economic growth. The author also addressed the problem of misuse and interpretation of those terms. While economic growth is traditionally sought in a way that compromises sustainability, the same happens in the opposite direction. Further, the concept of sustainability is often misused with the goal of obtaining approval for incremental improvements and the concept of zero waste is commonly seen as unrealistic, since it is not possible to be achieved in the incremental system.

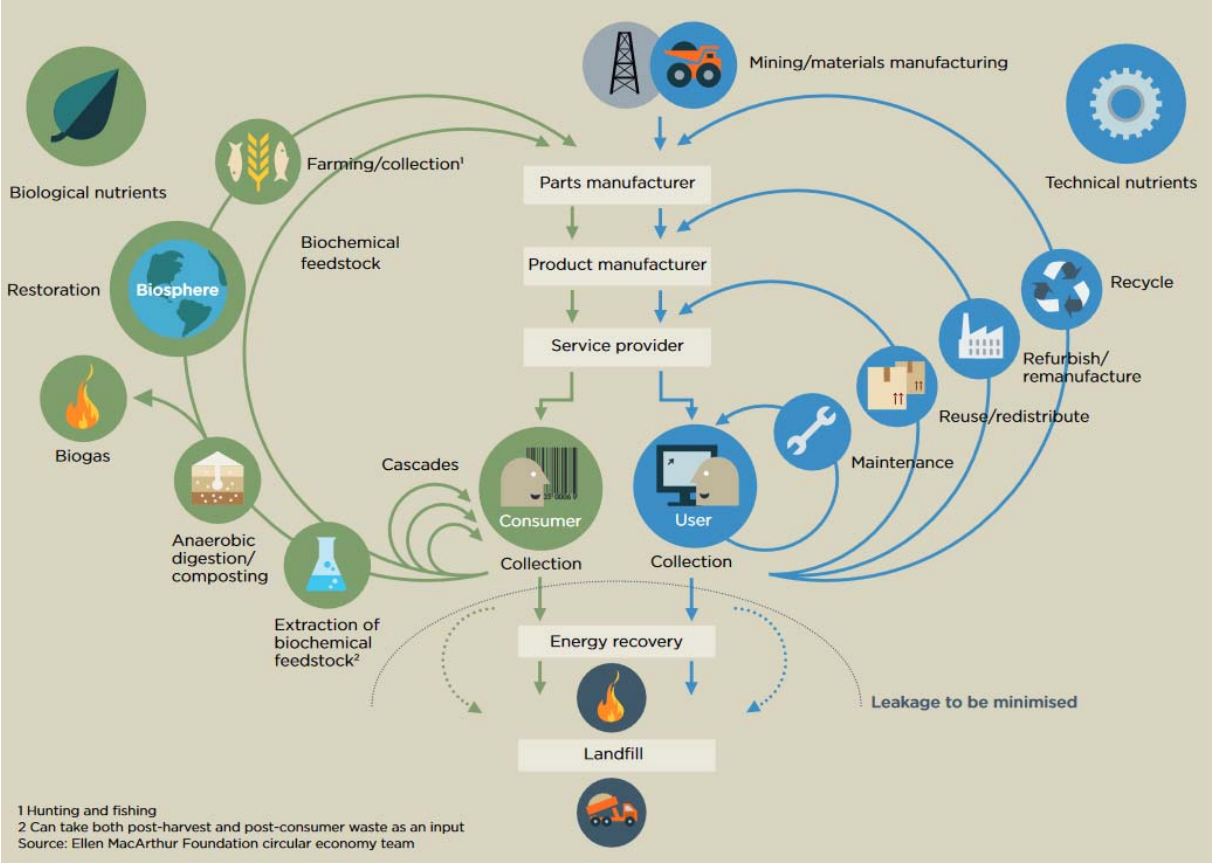
The German Parliament, in 1996, was the first at international level to pass a law concerning circular economy. It has been guided by some aspects from the model, such as the waste and pollution prevention by changing the technology to a cleaner production; the better reuse and recycling of waste; a different economic pattern of production, consumption, reuse, recycling and avoidance of waste through the adoption of economic tools and society mobilization; and the development of a legal system heading to a circular economy (BILITEWSKI, 2012).

With this different way of thinking from the circular model, the traditional linear economic growth, relying on resource consumption, is transformed into one relying on eco-resource recycling throughout the whole process. From resource input to waste disposal, the circular economy represents a clear preventive approach: “In its broadest sense, the circular economy represents a development strategy that maximises resource efficiency and minimises waste production, within the context of sustainable economic and social development” (GREEN ALLIANCE, 2011, p.2).

According to Bilitewski (2012), the concept has been changing traditional patterns of economic growth and production. While the traditional view sees the economic systems as

linear, with the resources being used in the production and thrown away after consumption, the circular system connects the use of resources with the waste of residuals. In this sense, what is seen as waste in the linear system represents a resource in the circular economy, which should go back to the production system after the consumption.

Figure 3 - The material flow in the circular economy



Source: Ellen MacArthur Foundation (2012, p.24)

Figure 3 demonstrates the material flow in the circular economy model for both biological and technical based nutrients. Although with different characteristics, approaches may be taken to improve the use of both. For the technical based nutrients, which is the case for the electronics, it is pointed out maintenance; reuse or redistribution; refurbishment or remanufacturing and only then recycling as a final option to put the product back into the economy system after its use. The model proposes that the industrial system should be regenerative both by intention and design, meaning that the disposal of the product is already thought in its design, in order to remain a resource even after use.

The Ellen MacArthur Foundation (2012) defends an upcycling approach, in contrast to the downcycling approach from the linear model. More specifically, the downcycling approach is the recycling of materials as an end-of-pipe solution, which decreases the material value and usability, as it is not designed for recycling. Instead, the idea of the upcycling process in the circular model is the opposite, meaning that the resources continue to have value even after use, since they are designed for recycling. Further, the model defends that:

> […] it replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models (ELLEN MACARTHUR FOUNDATION, 2012, p.07).

Taken as such, the concept of circular economy may seem simple. However, when it comes to the implementation of such precepts or principles, things are much more complex. Taking into account all different actors present in the life cycle of a single product, there is the need of a high level of planning and coordination involving the whole chain for the circular economy to be put into practice, from the design to production, consumption and disposal/recycling.

Therefore, divergences in views, rationalities and objectives among stakeholders require close coordination and special institutional conditions in order to converge towards a new way of conceiving and doing things. Still, incentives and new policy orientations and regulations, whatever the scale, may help in the process for shifting to this new approach.

3.3 Electronic devices and electronic waste

The current section of the literature review deals with electronic devices and electronic waste. Divided in two parts, the first one brings the definition and composition of electronic devices. The second part discusses some of the environmental impacts and the recycling process of the electronic waste.

3.3.1 Definition and composition of electronic devices

The electronic devices are products to which its operation depends on the use of electromagnetic fields or electric current. They may be categorized mainly into four separate

lines, as presented by ABDI (2012). The white line includes refrigerators and freezers, washing machines and dishwashers, stoves, tumble dryers and air conditioners. The brown line concerns monitors and televisions of LCD tubes, plasma, LCD and LED, DVD and VHS players, audio equipment and camcorders. The mixers, blenders, electric irons, drills, hair dryers, juicers, vacuum cleaners and coffee makers fall on the blue line. Finally, the green line includes desktop and laptop computers, IT accessories, tablets and mobile phones.

Electronic devices have a series of materials in their composition. Due to the diverse range of product types, in addition to the change in the products' composition over time, it is difficult to generalize the materials present on the electronic devices. However, the materials that commonly appear in their composition may be categorized into ferrous metals, nonferrous metals, plastic, glass and others. On average, nearly half of the electronics' weight is due to the presence of iron and steel, while more than 20% of the weight is due to plastic (WIDMER, 2005).

In the case of computers, Acosta, Wegner and Padula (2008) indicate that the most abundant materials are steel, plastic, aluminum and silicon. Especially for the manufacturing of the chips and boards, heavy metals such as cadmium, mercury and lead are sometimes used, which have pollutant effects on the environment and can cause health problems. Widmer (2005) corroborates by affirming that the electronics may contain over 1000 different substances, in which many of these are toxic.

While the electronic devices have toxic substances on their compositions that are difficult to be safely removed, they also have precious metals with high value on the market. While it is possible to find around four grams of gold in each device of an old computer, the rate is lower on the new devices, around one gram of gold per computer. Other common metals are also found in high rates, such as copper that may be present in up to 20% of the total products' composition (SODERSTROM, 2004 apud WIDMER, 2005).

3.3.2 Electronic waste: environmental impacts and recycling process

When the electronic products achieve the end-of-life period, they may be called by different denominations, such as electronic waste, e-waste or waste electrical and electronic equipment (WEEE).

The strong growth of technological innovations and the consequent decrease of the electronic products' life cycle are important factors for the increase in the e-waste. "During the

eight-year period up to 2000, computer purchases doubled in the United States, yet during the same period they tripled in Switzerland and increased more than six times in Brazil" (MACZULAK, 2010, p.38).

The number of electronic equipment entering the markets in both emerging and developed countries has been growing rapidly. Estimations from the United Nations University shows that between 8.3 and 9.1 million tons of electronic waste were produced between the 27 members of the European Union in 2005. The United States, which is the largest e-waste generator in the world, produced three million tons in 2007, to which less than 14% was recycled (OLIVEIRA; BERNARDES; GERBASE, 2012).

In Brazil, the information about electronic waste generation is not so widespread. However, the increase in the power of consumption and the country's advances have made the generation of e-waste also to grow. Schluep et al. (2009 apud OLIVEIRA, BERNARDES; GERBASE, 2012) indicate that Brazil is the second largest e-waste generator among the emerging markets, after only to China.

Due to their composition, the electronic devices can be extremely harmful to the environment. As highlights Acosta, Wegner and Padula (2008), the contamination may occur already in the manufacturing process, as toxic substances are used in the production process such as acetone, ammonia, dichloromethane, glycol ether, methanol, methyl ethyl ketone, Freon 113, sulfuric acid, toluene, xylene and trichloroethylene. The high consumption of water and energy, in addition to the generation of toxic waste are also related to the impacts resulting from the manufacturing process.

Because of the toxic substances in its composition, the e-waste represents a big threat both to the environment and to the human health when not having a proper destination and treatment. Thus, corroborating Acosta, Wegner and Padula (2008), such equipment should not be destined to landfills. Instead, it should have a different treatment from the general waste.

> The components of electronic products create an environmental hazard, but before these components can cause their harm, e-waste fills public landfills because it has never been part on an efficient recycling program. Even worse, tons of e-waste are discarded in illegal dumpsites where no monitoring takes place. Older model computers, monitors, and televisions are bulky and take up landfill space, and, as they weather, they begin to leak a steady stream of hazardous materials into the environment. (MACZULAK, 2010, p.39)

The lead, which is very commonly used as solder, has a strong impact on the environment when found in high amounts. In areas of retro processing in emerging countries, where it is possible to find millions of tons of electronic waste, the high amount of the metal is

a concern. Silveira and Chang (2012) exemplify that, in the case of China, high concentrations of heavy metals have been detected in rice crops, such as lead, cadmium and mercury. In addition to soil pollution, lead can also contaminate plants and, consequently, humans.

The substances present in the electronics, especially in the circuit boards, can cause serious problems to the human health, such as neurological and reproductive problems. Besides cancer, the lead can cause problems in the central nervous system, immune system and kidney (SILVEIRA; CHANG, 2010).

There are also components in the plastic that serve as flame retardants, such as polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), which are also dangerous. Such components can cause cancer and disorders in the immune and endocrine system. Moreover, when burned, they emit highly toxic substances into the environment, polluting the soil and the water (SILVEIRA; CHANG, 2010). In the case of improper recycling, which is very commonly performed in the emerging countries where the devices are burned without any type of control, the generation of such toxins is a serious problem.

Even with the increasing amount of electronic waste and its continuous growth trend, the electronic recycling process is still incipient, both at the national and international level. While there are companies specialized in the appropriate recycling process in developed countries, Li and Tee (2012) point out that much of the electronic waste produced in industrialized countries ends up being exported to emerging countries such as some in Asia, usually made illegally.

In the emerging countries, the recycling process is very commonly done intensively with low technology and without any regulation. Besides, workers operate informally without proper working conditions and limited access to basic services. Because the process is manually done and without protective equipment, there is a direct exposure of workers to metals that are harmful to health. Pollution is another problem in such countries, considering the use of rudimentary recycling techniques, without any concern for the disposal of residues. As environmental regulations and labor costs tend to be much lower than in the developed countries, this option leads to lower costs of businesses (LI; TEE, 2012; OLIVEIRA; BERNARDES; GERBASE, 2012).

In Brazil, Guarnieri (2011) states that it is still difficult to recycle an entire device. Most of the companies specialize in the retro processing of one type of material only, not the entire product. The estimations show that, based on the Brazilian formal market, less than 1% of the electronic waste has an adequate environmental destination.

Regarding the recycling process itself, in order to occur without damaging the environment, a high level of technology is required in addition to a manual process, which entails high costs. Oliveira, Bernardes and Gerbase (2012) indicate three stages that are usually part of the recycling process in the developed countries when properly carried out, which are the disassembling, upgrading and refining stage.

For the disassembling stage, although sometimes shredders are used to mechanize the process, this method is not efficient for the recovery of precious metals. Therefore, the dismantling stage should be made manually and selectively, as a way to separate the hazardous and valuable components for special treatment. On the upgrading stage, there is the mechanical or metallurgical process, with focus on the previously selected components. On this stage, the metals and materials are separated by shredding or grinding and, after size reduction, sorted according to various features of size, density, weight, magnetic properties, among others. Finally, the refining takes place using a chemical process, in order to purify the recovered materials and make them useful again. (OLIVEIRA; BERNARDES; GERBASE, 2012).

In addition to the high costs in the recycling process itself, another limitation is related to the high costs in the reverse logistics process. The presence of hazardous substances in its composition demands an utmost care in the transportation. Moreover, there is sometimes the need of transporting the electronics over long distances. Thus, a good logistics planning is essential and the decision-makers must consider the reverse logistics costs for the organization to remain competitive in the market (LI; TEE, 2012). The lack of government incentive policies is also mentioned by Lau and Wang (2009), resulting in high costs of logistics.

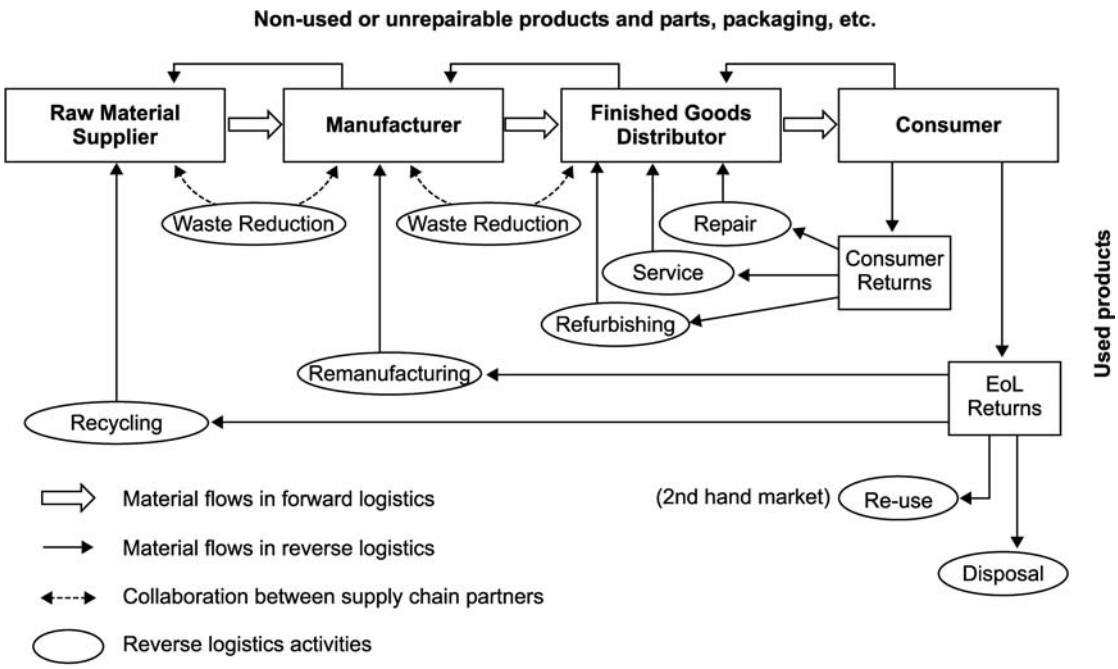
Another point regarded by Lau and Wang (2009) is the difficulty in predicting the amount of e-waste available for recycling. Although the products have high added value, the recycling process involves high costs. It needs, thus, a large amount of products available for the recycling process to be economically profitable, gaining in economy of scale.

3.4 Reverse logistics of electronic waste

The supply chain, from the perspective of logistics, does not end with the delivery to the consumer, but rather when the final disposal of the product takes place. Thus, in addition to the direct logistics process, the reverse logistics process takes place, defined as “the process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the

point of origin for the purpose of recapturing value or proper disposal" (ROGERS; TIBBEN-LEMBKE, 1998, p.2).

Figure 4 - Basic activities and flows in reverse logistics



Source: Lau and Wang (2009, p.449)

As shown in *Figure 4*, there are several ways of possible paths in the reverse logistics process for the products at the end-of-life (EoL), which makes it possible to optimize the products' life cycle and reduce their environmental impacts. The end-of-life products may be discarded or reused. More than that, they may also be remanufactured, so to extend its useful life, or recycled, so to regain its value and go back to the beginning of the chain (ACOSTA, 2008; LAU; WANG, 2009).

The remanufacturing is an industrial process of disassembly and restoration of the products' components, so that they are reintroduced in the assembly operation for new parts. Therefore, this process does not prevent innovation from happening. Besides, it retains part of the added value, as the mixing of remanufactured components with new pieces may occur, adding value to the remanufactured product (GEHIN; ZWOLINSKI; BRISSAUD, 2008; KHOR; UDIN, 2013).

In the recycling process, which is the most common among the EoL strategies, the product loses its added value, since it loses its functionalities (GEHIN; ZWOLINSKI; BRISSAUD, 2008). On the other hand, the raw material is partly recovered, which can be

reused in the same sector or in alternative sectors that require such elements in the manufacturing process of its products. (ACOSTA; WEGNER; PADULA, 2008; KHOR; UDIN, 2013).

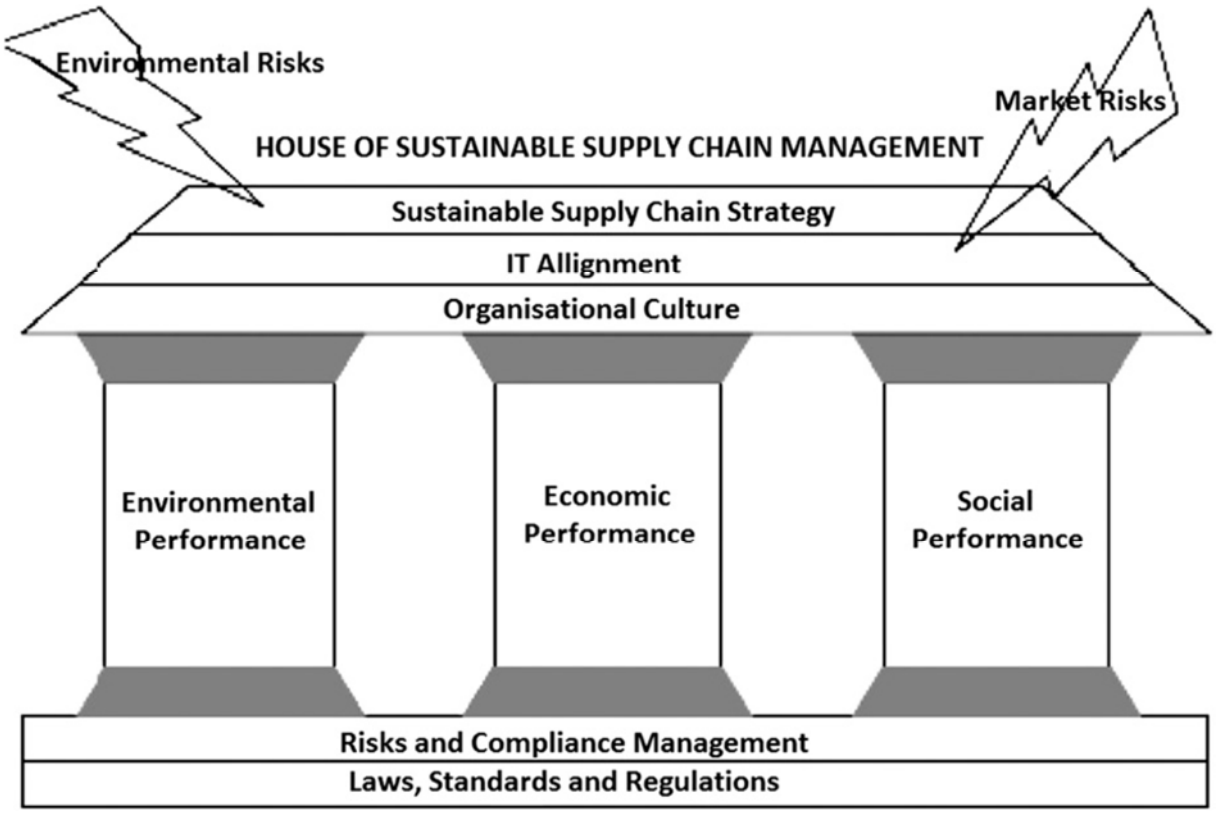
Ballou (2004) points out that the final product may be returned to the original source due to environmental legislation reasons or even because the reuse can make sense in economic terms. He also argues that the reverse logistics process may take place either by benefiting from the direct logistic path or by requiring a separate project itself. In any circumstances, the scope of logistics planning and control needs to include the reverse channel.

According to Guarnieri (2011), the extraction of natural resources, together with the increasing scale of production are factors that have stimulated the exploration of the environment and increased the amount of waste generated. The technological innovations, together with the changes in consumption patterns, have made the environmental disasters to increase, as opposed to a growing lack of resources. As a result, logistics has been gaining more space and strength. In this sense, Ballou (2004) argues that the growth in the service sector, the information technology and the environmental issues have been some of the key aspects for creating new opportunities in the logistics management field, which should continue to support the logistics in the future.

Taking into consideration the growing importance of environmental issues, the society has begun to raise an environmental awareness and to demand actions on the subject from governments and companies, inserting the discussion of sustainability in the business environment. Therefore, the reverse logistics is an essential tool, as it represents a strategy to operationalize the process of come back for the products at the EoL, taking into consideration that the simple disposal of it is not anymore accepted on the new business context (GUARNIERI, 2011).

With that in mind, it is interesting to comment on the sustainable supply chain management (SSCM) concept described by Zailani et al. (2012), with the main idea of integrating environmental, social and economic issues for human development. Although considered as a new field, it has been gaining importance in the recent years. The term SSCM is strongly linked with other concepts, such as green design, products recovery, waste management and reverse logistics. In order to have an efficient SSCM, the strategy needs to be built on the three pillars of environmental, social and economic performance. It also needs to be aligned with the information technology and the organizational culture of the company, just as presented in *Figure 5* (ZAILANI et al., 2012).

Figure 5 - House of sustainable supply chain management



Source: Teuteberg and Wittstruck (2010 apud Zailani et al., 2012, p.331)

Rogers and Tibben-Lembke (1998) point out to some factors that affect the reverse logistics practices. External factors such as public awareness, legislations and the partners' support in the supply chain may represent either incentives or barriers to the process. Lau and Wang (2009) also propose some initiatives concerning external factors for the electronic industry, such as initiatives from the government, like education of citizens and assistance in establishing return collection channels. The government also needs to set up regulations to reverse logistics practices for a long-term sustainable development. Further, it needs to provide economic incentives to make it viable for small manufacturers to start programmes. Manufacturers should also apply more green design for their products and invest in reverse logistics information systems and technology, in order to increase efficiency. There is also a need for the various actors of the supply chain to collaborate with one another, so that to optimize the whole process.

Internal factors also affect reverse logistics, as companies take into account strategic and operational factors. Reverse logistics plays an important role in the companies' strategy due to the fact that it may be considered as just a need to abide by laws or as means to gain

long-term profit. As developing a self-support system involves a heavy investment, financial considerations are also important. Management skills are also fundamental when considering a reverse process, considering that the demand and responsibilities are higher than with just the usual flow. Establishing a self-support system also requires technological equipment and trained personnel. Factors such as company policies, strategic planning and the quality of the returned products also influence the reverse logistics practices. In addition, the reverse logistics process usually involves more than one company, which requires a holistic approach (LAU; WANG, 2009; ROGERS; TIBBEN-LEMBKE, 1998).

The supply chains should be environmentally friendly, using as few resources as possible and being closed-looped. While in the past this process only focused on the system of production and delivery from the raw material stage to the final consumer, today the supply chain management demands different practices that may be defined in six topics: environment, ethics, diversity, working conditions and human rights, safety, philanthropy and community involvement. Such practices may be environmentally friendly purchasing and packaging, in addition to sustainable transportation. Sustainable warehousing and reverse logistics are also mentioned, with an efficient return and recycling or disposal of end-of-life products (ZAILANI et al., 2012).

By examining SSCM practices in the manufacturing firms in Malaysia, Zailani et al. (2012) have been able to prove that such practices affect the performance of the firm. This shows that these sustainable practices in the supply chain may bring value not only to the external environment, but to organizations as well, contributing also to the sustainable development of the country in the big picture.

Lau and Wang (2009) emphasize that, although reverse logistics may help to maintain a sustainable development and to generate additional profits, most manufacturers in the electronic industry of China are uninterested in this investment. Another point mentioned is that the academic researches dealing with the topic of reverse logistics for electronics, both theoretical and empirical, tend to be about developed countries, so that there are few studies about such practices in the newly industrialized countries.

It is important to highlight that, especially for the subject of electronic waste, the high reverse logistics costs involved compel companies to look for the issue from a long-term strategic perspective. In developed countries, some directives as the Waste Electrical and Electronic Equipment (WEEE) and the Restriction of Hazardous Substance (RoHS) of the European Community (EU) have made the reverse logistics a fundamental part of the supply chain process for the electronic industry, as it is discussed on the chapter about *The European*

Scenario. While in developed countries the major manufacturers have implemented several reverse logistics actions, in emerging markets this process still has a lot to improve, just as presented by Lau and Wang (2009) in the case of China.

With the fast-growing population and consumption, in contrast to the decrease in available resources, the subject of sustainability becomes more and more important every day. More than fulfilling legal obligations, sustainability may be seen as a matter of strategy, as it is discussed further in the section *Strategy for the reverse logistics and recycling of electronics*. In order to remain competitive in the market, companies have today to consider the environmental impacts when doing business and this has a strong link to the way supply chains should be designed.

3.5 Strategy for the reverse logistics and recycling of electronics

Although strategy plays an important whole in the business world today, it goes back many centuries in history. Already present as military strategy on the ancient wars, a notable example is the book *The art of war* from the Chinese strategist Sun Tzu. Mintzberg et al. (2007) state that until today there is no universal and single definition for strategy and, while some authors include objectives and goals as part of its concept, others make a distinction between them.

One of the definitions of strategy comes from Mintzberg, as he presents strategy divided into five P's, which are strategy as plan, as ploy, as pattern, as position and as perspective. Following his line of thought, strategy is a plan by representing a course of action, which is both created before actions and consciously developed on purpose. Strategy is also part of a ploy, as it may be a way of deceiving competition. Strategy is a pattern, as it represents consistency in the behavior, which may be either intended by a plan or not. Strategy is also a position, as it is the result of the way the organization acts on a specific environment. Lastly, strategy is a perspective, as representing not only the position of the organization on the external environment, but also the internal way of acting and reacting to such environment (MINTZBERG et al., 2007).

Concerning the different views on strategy, there are mainly two different ones, which are the resource-based view and the market-based view. The resource-based view of strategy focus in utilizing the resources of the organizations to develop its strategy, working with the inside-out approach. The market-based view of strategy focus on building its strategy according

to the nature and trends of the environment, working as an outside-in approach (GRÜNIG; KÜHN, 2008).

In this resource-based view, the term resource is used not only to include the material, human and financial assets, but also skills, competencies and other possible company's potentials. According to Barney (1991 apud GRÜNIG; KÜHN, 2008), there are four characteristics that the resources must have to generate sustainable competitive advantages, which are rarity, ability to meet customer needs, imperfect imitability and imperfect substitutability.

The main conduct of the resource-based view is that "the use of these resources to create products or services meeting customer requirements in specific markets leads to permanent competitive advantages" (GRÜNIG; KÜHN, 2008, p. 194). On the market-based approach, the main conduct is that "firms use these possibilities by choosing a competitive strategy and building the required resources" (GRÜNIG; KÜHN, 2008, p. 194).

There are several schools of thought towards strategy. Mintzberg, Ahlstrand and Lampel (2000) identify in their book *Strategy Safari* ten different schools of strategy, which are the design school, the planning school, the positioning school, the entrepreneurial school, the cognitive school, the learning school, the power school, the cultural school, the environmental school and the configuration school.

The design, the planning and the positioning school have a prescriptive nature, focusing on how the strategies should be formulated. The next six schools focus on describing how the strategies work in practice, taking into consideration aspects in the formulation of such strategies. The last one, the configuration school, is a combination of the others, especially in the sense of integrating the formulation and the content of strategies with the organizational structures and its contexts (MINTZBERG; AHLSTRAND; LAMPEL, 2000).

All schools of thought have emerged in different stages of the strategic management development and, while some remain strong over time, others have declined. Mintzberg, Ahlstrand and Lampel (2000) state that, while some of them have an orientation towards arts or work, the planning and the positioning schools are mostly oriented towards science.

Although the positioning school is similar in many aspects to the design and planning school, it has added the focus on the importance of how strategies are conducted, instead on only how they are formulated. According to Mintzberg, Ahlstrand and Lampel (2000), the most important aspect of this school in relation to the other schools of prescriptive nature is that it has a unique idea, by stating that few key-strategies are necessary for a sector of the industry, which are the ones that may be used against competition. It has, thus, established limits for

possible strategies, giving importance to the way companies are able to defend themselves in the market as a possible indicator of their profitability.

For the current research, especially when analysing the companies in the case studies, the strategic approach taken is the market-based view, with a special focus on the positioning school. In the case of the management of electronic waste in Brazil, the researcher has taken into consideration that it is an external force, represented mainly by the current laws and policies taken towards the subject, that are forcing the electronics industry to adapt its strategies. In order to remain competitive in the market, many companies have been adopting more environmentally friendly practices towards the recycling of electronic waste. In response to this external force, companies may either apply the minimum procedures required by the laws or take advantage of such obligation, transforming the sustainable practices required into part of the company's strategy.

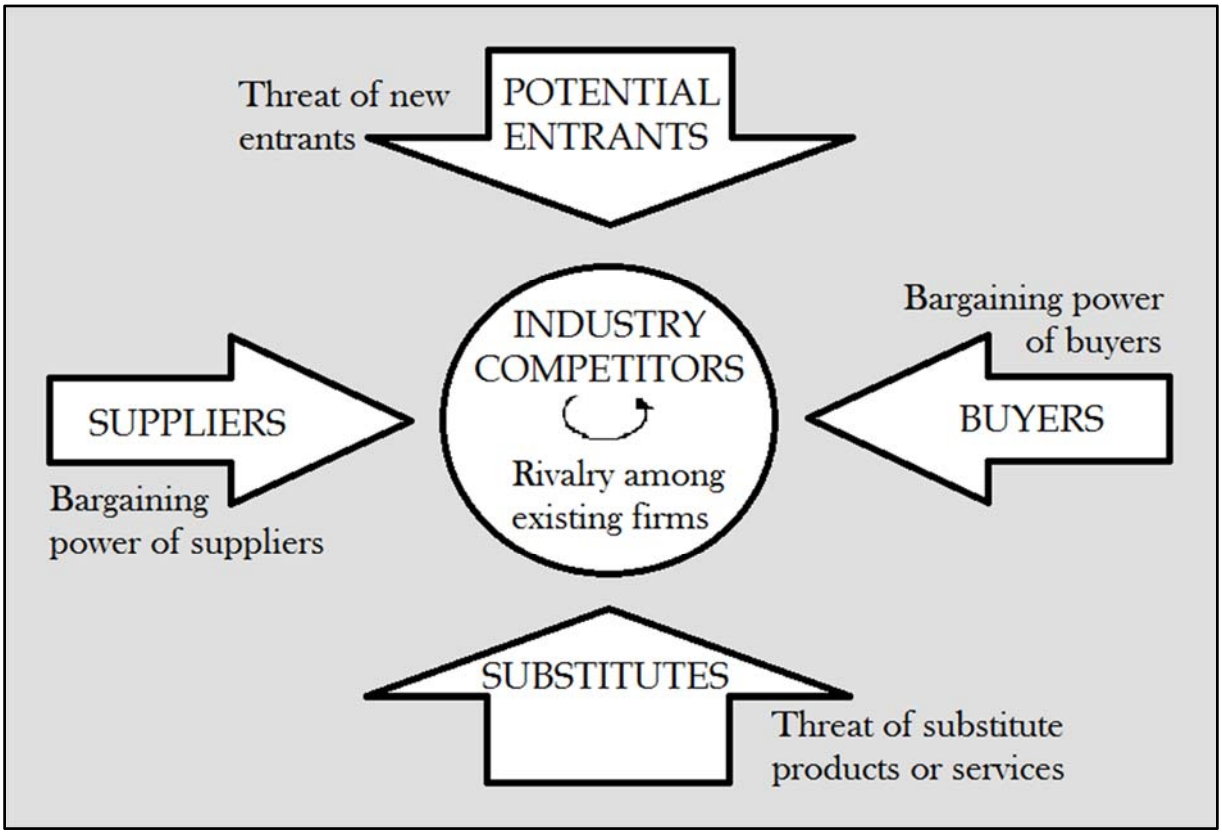
One of the key scholars of the positioning school is Michael Porter. It was in 1980 that he published the book *Competitive Strategy*, being one of the marks of the strong activity towards the school. By having inspiration on the industrial organization, Porter has focused on explaining how the behavior of all industries works, instead of individual ones (MINTZBERG; AHLSTRAND; LAMPEL, 2000).

Porter (1980) presents four key elements that limit the possible accomplishments of a firm, which are the industry's opportunities and threats, the broader societal expectations, the personal values of the key implementers and the company's strengths and weaknesses. While the first two are factors external to the company, the last two are internal factors. All these four elements affect the way a competitive strategy should be formulated.

When developing a competitive strategy, Porter (1980) explains that the company needs to decide how its business will compete in the market, what are its goals and what policies such goals will demand. By combining the specific goals with the necessary policies, it is then possible to develop a competitive strategy. The key operating policies may come from marketing, product line, sales, distribution, manufacturing, labor, purchasing, finance and control, research and development, or target market.

Porter (1980) presents a framework about the forces underlying competition in industries, to which he designates as the five competitive forces. This tool may be used by companies to identify the differences from their competition in terms of characteristics and evolution, so that to establish a good strategy when positioning themselves in the market.

Figure 6 – Porter's five forces



Source: Developed by the author based on Porter (1980)

As presented in *Figure 6*, the "five competitive forces - entry, threat of substitution, bargaining power of buyers, bargaining power of suppliers, and rivalry among current competitors - reflect the fact that competition in an industry goes well beyond the established players" (Porter, 1980, p. 6). All these forces indicate, when analysed together, the profitability and competition power of an industry. One or some specific forces may be stronger than the others in an industry, thus representing the key competitive forces when formulating the industry's strategy.

After examining the five competitive forces, Porter (1980) indicates three possible strategic approaches that may be taken by industries to surpass others. The three generic strategies described are the overall cost leadership, differentiation and focus. Although more than one strategy could be applied at the same time, it is mostly common for industries to focus on one of the generic strategies, as its implementation demands true commitment and organizational arrangements.

The strategy of overall cost leadership is based on the implementation of several policies for obtaining a low-cost position in the market. This strategy usually requires some advantages,

such as easy access to raw materials or a high relative market share, in addition to heavy capital investment in equipment and sometimes initial losses, until being able to build market share. After achieving the low-cost position, this strategy tends to proportionate high margins, which may then be reinvested for maintaining such position (PORTER, 1980).

The second strategy presented by Porter (1980) is of differentiation, which has the main aim of creating a product or service seen as unique industrywide. Many approaches may be taken in order to achieve that, such as technology, design or brand image, dealer network or customer service. Such strategy does not ignore costs, but also does not see it as a primarily target in the formulation of strategy. When achieved, the differentiation creates a defensive position to deal with the five competitive forces.

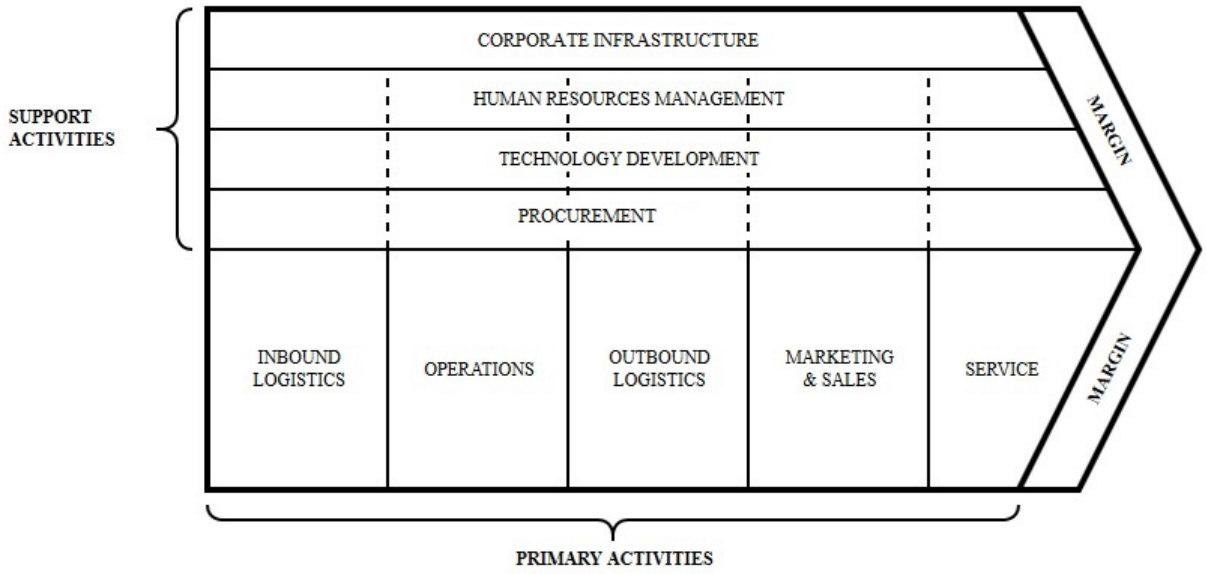
The last generic strategy from Porter (1980) is the focus one. This strategy is based on focusing on a particular aspect of the firm, such as a geographic market, a product line or a group of buyers. With this in mind, the firm's policies are designed in order to obtain the best performance in the specific aspect chosen. It may bring as result both differentiation and lower costs for this narrow market, instead of the market as a whole.

Another important structure introduced by Porter, in his book *Competitive Advantage* from 1985, was the one of the value chain. In this book, he defends that a company's competitive advantage is based on its value chain. "As Porter defines it, a competitive advantage refers to a situation in which one company manages to dominate an industry for a sustained period of time". (BROCKE; ROSEMANN, 2010, p. 46) Thus, the companies' strategies are strongly connected to how they organize their activities in these value chains (BROCKE; ROSEMANN, 2010; MINTZBERG; AHLSTRAND; LAMPEL, 2000).

Porter divides the companies' activities in primary activities and support activities, as explained by Mintzberg, Ahlstrand and Lampel (2000). Primary activities involve inbound logistics, operations, outbound logistics, marketing and sales and service. The support activities involve corporate infrastructure, human resources management, technology development and procurement. The framework of Porter's value chain is shown in *Figure 7*.

Both the primary activities and the support activities have a margin of profitability based on how the value chain is managed. This structure represents a systematic way of examining the way the companies' activities work and interact with one another and evidences how all the activities are interconnected (BROCKE; ROSEMANN, 2010; MINTZBERG; AHLSTRAND; LAMPEL, 2000).

Figure 7 – Porter's value chain



Source: Adapted from Mintzberg, Ahlstrand and Lampel (2000, p. 110)

As it is discussed in the following chapters, part of the research brings a comparative analysis of the electronic recycling scenario in different contexts, more specifically in Brazil and in Europe, which makes it relevant to present the diamond model. In the book *The Competitive Advantage of Nations*, Porter (1990) develops an economic model in order to justify why certain industries may be more competitive depending on their locations.

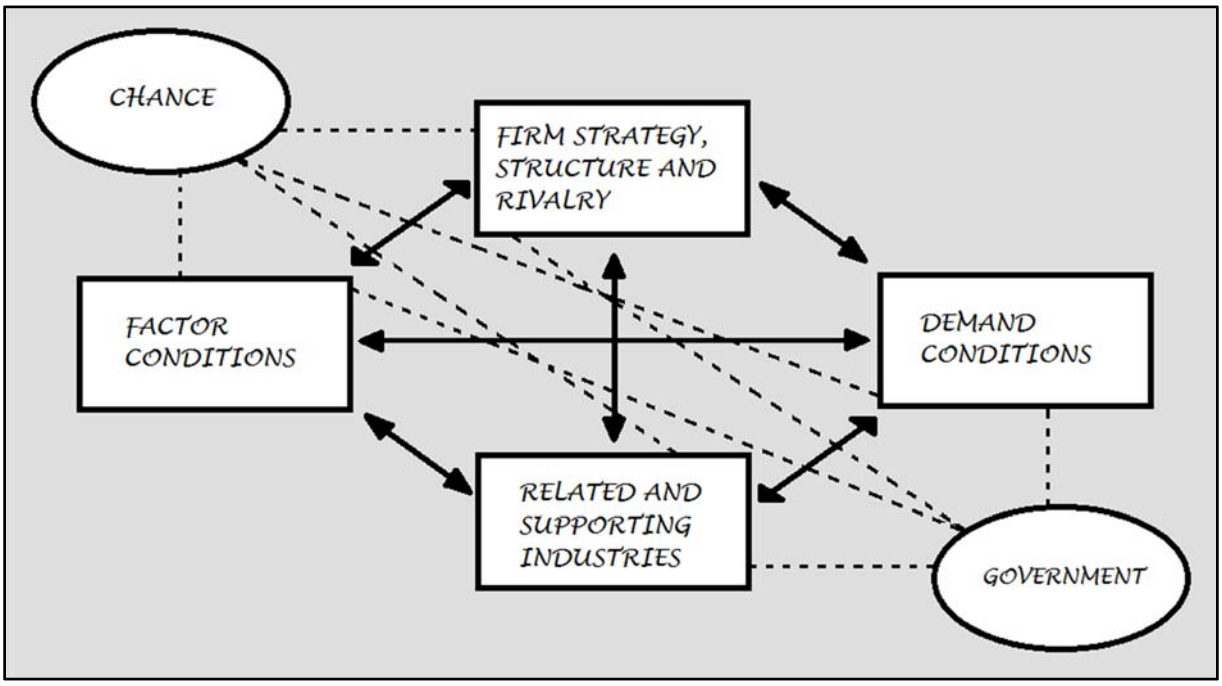
Figure 8 brings the diamond model with the determinants of national advantage. According to the diamond model, the competitiveness of a country is the result of four major determinants, which are the factor conditions; the firm strategy, structure and rivalry; demand conditions; and related and supporting industries.

The factor conditions represent the factors of production, which are the inputs like natural resources, labor, infrastructure and capital. Their efficiency and effectiveness in the industry influence their competitiveness in the nation. The firm strategy, structure and rivalry, representing another determinant, regard how the industry is created and managed. In addition, it is connected to the rivalry in the home base, which may pressure the industry towards innovating approaches for competing in the market (PORTER, 1990).

The demand conditions, that is, the market buyers' demands, are also important players in order for the industries creating competitive advantage, as proposed by Porter (1990). Having strong impact on the production, such demands may pressure industries to offer different

products or services, which usually encourages them to innovate so to remain competitive in the market.

Figure 8 – Porter's diamond model



Source: Developed by the author based on Porter (1990)

Other determinant of the Porter's diamond, as indicated in *Figure 8*, concerns the related and supporting industries. Such industries produce inputs that may influence the national system in terms of internationalization or innovation, for example. Related industries may work in different areas, such as manufacturing, distribution and technology development. In any case, they are industries that either share activities in the value chain or involve complementary products (PORTER, 1990). Considering that, especially when analysing multinationals, there is a big variety of actors involved in the production dynamics, these evidently play important roles in the system. The way an industry interacts with its suppliers and related industries, thus, affects its power to compete in the market.

In addition to the four major determinants, Porter (1990) adds two other variables that complete his theory and may influence the national system. One of the variables is chance, which are out of the company's control and may represent an important role for industries to gain competitive advantage. Examples of chance events are technologies breakthroughs, wars and inventions. The other variable mentioned is the government, which may either represent a

positive or negative aspect towards national advantage. At different levels, policies, regulations and diverse investments may influence the complete national system.

It is possible to stablish various connections between the Porter's diamond model and Porter's five forces model. Concerning rivalry, it is interesting how the author presents different views on each model. In the five forces model, high rivalry is presented as not attractive to the industry. Nevertheless, when seen from the global perspective of the diamond model, high local rivalry is presented as attractive to industries. On the long run, this local rivalry demands industries to improve and innovate, thus resulting in less global rivalry.

Strategy is closely connected with innovation, subject that is discussed in more detail in the next section, *Innovation and uncertainties in the recycling of electronics*. Tidd and Bessant (2015) defend that the company's specific knowledge and the way the company manages it is an essential point for obtaining competitive success. As such, an essential part when formulating the corporative strategy should be of building up on this company's specific knowledge, which represents the innovation strategy.

In order to establish an innovation strategy, it is necessary that the company is able to adapt itself to the external environment, filled with uncertainties, changes, market demands and competitive threats. Taking into consideration the high complexity and the uncertainty aspects, Tidd and Bessant (2015) defend that an incremental strategy has more chances of success than a rational strategy of innovation, due to the incremental one being constantly adapted to the scenario and knowledge acquired. The authors also relate the innovation strategy with the concepts discussed by Porter, as he identifies the technological advances as impacting the competitive threats and opportunities and, as such, emphasizes the importance in developing and maintaining the company's own technology.

Returning to the section of *Reverse logistics of electronic waste*, a supply chain in closed loop can be a part of the company's strategy, as a way to achieve a sustainable development. Besides, "an efficient and effective reverse logistics management strategy has become a crucial weapon for a firm to defeat its rivals in the same industry" (LAU; WANG, 2009, p.449).

It is interesting to comment that, when applying sustainable practices as part of the company's strategy, the operations do not necessarily need to be taken by the company on its own. Like presented by Lau and Wang (2009), many large corporations have been focusing on improving their reverse logistics strategy in order to achieve more sustainable production and consumption and, while some use their own self-support system to do this, others outsource to third-party logistics providers. With pros and cons, although a system for this usually requires

high capital investment, it may also bring valuable information to improve the manufacturing companies.

3.6 Innovation and uncertainties in the recycling of electronics

The current section is an adaptation from a paper presented at the *International Conference on Science, Technology, Engineering and Management* held in Paris (France) on 8 March 2015. Afterwards, it has been published in the *International Journal of Mechanical and Production Engineering*.

Divided in three parts, the first one brings some insights about innovation. The second part talks about uncertainties and complexity. The third and last part is the core of the section, which brings the systematic literature review of the main uncertainties identified on the electronic waste recycling business, based on a search on the *Web of Science* platform.

3.6.1 Innovation

Innovation is not a new concept. Taking into account the natural behavior of thinking about new and better ways of doing things and putting them into practice throughout history, it has arguably taken part in the evolution of humanity.

For Fagerberg (2005), innovation started to be considered a separated field of research in the 1960s and, since then, it has gained strength in an environment of economic and social change. The subject of innovation requires a combination of insights from several disciplines and from different perspectives. It is, thus, multidisciplinary and a systemic phenomenon, representing the continuing interaction of different organizations and actors.

According to Schumpeter (2012), innovation is a driver for the economy by a qualitative change and has five different types by introducing something new. As such, it may come from a new product, new sources of supply, the exploitation of new markets, new or different methods of production and new forms of competition. Therefore, innovation can come from a variety of actions. Further, Porter (1990, p.45) defines innovation as:

> […] to include both improvements in technology and better methods or ways of doing things. It can be manifested in product changes, process changes, new approaches to marketing, new forms of distribution, and new concepts of scope. […] Much innovation, in practice, is rather mundane and incremental rather than radical. It depends more on accumulation of small insights and

> advances than on major technological breakthroughs. It often involves ideas that are not 'new' but have never been vigorously pursued. It results from organizational learning as much as from formal R&D. It always involves investment in developing skills and knowledge, and usually in physical assets and marketing effort.

There are several factors that create the need for innovation, which may be summarized as “technological advances, changing customers, intensified competition and the changing business environment” (GOFFIN; MITCHELL, 2010, p.2). The first driver makes the creation of knowledge to happen at a large speed, which requires the firms to monitor constantly the new technologies in order to maintain themselves competitive in the markets. The changing customers and needs concern the disappearance of traditional market segments and the need for companies to adjust their products and services accordingly. The third factor, intensified competition, occurs mainly in response of globalization, with the decrease in logistics costs and the increase of foreign competition. The last driver presented by Goffin and Mitchell (2010) is the changing business environment and is directly connected with the worldwide open market economy and the short products life cycles.

The innovation drivers presented by Goffin and Mitchell (2010) may be easily connected to the electronic industry and the electronic waste issue in all the four aspects presented. While electronics were hardly disposed of some years ago, the reality nowadays is of a short products’ life cycle and high rates of consumption. Globalization and internet purchasing also exacerbates the problem, so that customers have access to a vast array of new products from different companies around the world. Therefore, it is easy to observe that innovation is strongly present for new electronic products. Nevertheless, there is still the need to innovate in the reverse cycle, such as collection approaches for electronic waste, and in the recycling of electronics, in order to find more environmentally friendly solutions to tackle the issue of a sustainable development.

Considered for a long time innovation as a random phenomenon, Schumpeter (2012) has developed an original approach against this practice, stating that economic and social development is a process of change and driven by innovation. He has presented three main aspects that must be considered in innovation: the need to tackle inertia; the need to innovate before competitors to benefit from the potential economic reward; and the uncertainty in all innovation projects. The last two aspects are strongly linked with entrepreneurship, demanding qualities such as leadership and vision.

3.6.2 Uncertainties and complexity

Considered one of the main scholars on the study about complexity and complex thought is Edgar Morin. Concerning education for the future, he addresses the high level of information acquired in the new generation and the need to find ways to deal with the unexpected:

> We should teach strategic principles for dealing with chance, the unexpected and uncertain, and ways to modify these strategies in response to continuing acquisition of new information. We should learn to navigate on a sea of uncertainties, sailing in and around islands of certainty (MORIN, 2001, p. 13).

Sargut and McGrath (2011), when discussing about business management, also defend the high level of complexity in which they are involved nowadays if compared to some years ago. Although complex systems have always existed, they have expanded from large systems to most of organizations nowadays, as result mainly from the information technology revolution. Complex organizations involve a high level of unpredictability and an unexpected interaction among systems. "Although single constituents may not remain in place and may eventually disappear, the system persists as it adapts to internal and external change" (ZELLNER, 2008, p.444).

While in complicated systems is possible to predict outcomes when the starting conditions are known, in complex systems there may be different outcomes due to the interactions of elements from the system. (ZELLNER, 2008; SARGUT; MCGRATH, 2011).

> Three properties determine the complexity of an environment. The first, multiplicity, refers to the number of potentially interacting elements. The second, interdependence, relates to how connected those elements are. The third, diversity, has to do with the degree of their heterogeneity. The greater the multiplicity, interdependence, and diversity, the greater the complexity (SARGUT; MCGRATH, 2011, p.70).

When dealing with collection and treatment of electronic waste, this can thus be considered a complex business. The high number of heterogeneous elements involved in the electronic waste business need to work in a connected way in order to succeed. Meijer and Hekkert (2007, p. 282) state that "steering sustainable development is problematic due to the ambivalence of goals, the uncertainty of knowledge about system dynamics, and the distributed power to shape system development". Zellner (2008, p.438) further addresses the environmental problems involved in systems with high degree of complexity and uncertainty:

> These problems persist due to the diversity of actors involved (partly addressed through participatory approaches), the public goods nature and unclear dynamics of the natural resources and functions with which they interact, and the 'silo approach' in various realms of public policy that does not readily recognize these interactions.

It is important to emphasize that, "as much as this complexity is a problem, it is also an opportunity" (ZELLNER, 2008, p. 438), when small behavioral changes may stimulate environmental transformation in a large scale. Those changes, as presented by Zellner (2008) should be explored and linked to their triggers by environmental planning, providing alternative perspectives on how to deal with complexity and take advantage from it.

Morin (2001) identifies seven key principles that should be essential in the education for the future, according to his conception of complex thought. In this sense, he proposes the following principles: Detecting error and illusion, principles of pertinent knowledge, teaching the human condition, earth identity, confronting uncertainties, understanding each other and ethics for the human genre.

Concerning the specific principle of confronting uncertainties, Morin (2001, p.66) argues that today "[...] the collapse of the myth of progress brings us awareness of historical uncertainty. Some progress is, of course, possible, but it is uncertain. This is compounded by uncertainties related to the speed and acceleration in our planetary era of complex random processes [...]". In this sense, it is indispensable to learn how to live and adapt to diverse uncertainties in different spheres of knowledge, in order to progress in the highly complex environment which society faces today.

Uncertainty has been used with different meanings in a number of fields and has had different approaches by different authors throughout time. Although it has been studied for a long time, still today there seems to have no consensus on its definition, classification and operationalization. There is also a lack of understanding for the different dimensions of uncertainty and their characteristics, magnitude and means to deal with them. A broad definition of uncertainty is presented as "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system" (WALKER et al. 2003, p. 5).

Regan (2012) states that considered to be one of the earliest attempts to define uncertainty is the perspective of Knight (1921), separating the concept of uncertainty from risk in the dimension of degree of uncertainty. This approach states that it is possible to attribute a probability distribution of events for risk and that it may be considered as a fake uncertainty. On the other hand, uncertainty has a higher degree of unawareness than risk and it is not possible

to calculate possible future outcomes for an action, so that there is randomness with unknowable probabilities.

Knight (1921) recognizes that entrepreneurs may benefit from uncertainties to produce economic value when making decisions in uncertain contexts where other economic actors would not. Since Knight, uncertainty has been studied further in different areas of knowledge and with different approaches, seen as an important issue in entrepreneurship and business models (REGAN, 2012).

There is a distinction in literature between objective uncertainty and perceived uncertainty. Supporters of the objective uncertainty argue that is possible to objectively measure uncertainty and that it depends on the environment (MEIJER et al., 2006). On the other hand, supporters of the perceptive view believe that an objective measurement is not possible, as it depends on the ways innovation is perceived by different actors (MILLIKEN, 1987).

The perceptive view states that uncertainty depends on the individual and defends that "building up interpretations about the environment is a basic requirement of individuals and organizations" (DAFT; WEICK, 1984, p.284 apud REGAN, 2012, p. 18). Taking into account that the focus of the present section is on the innovation behavior of the various actors involved in the context of high uncertainties of e-waste business, the perceived uncertainty view seems to be de most suitable to be studied further.

Milliken (1987) summarizes the inconsistencies and problems in the definition and measurement of environmental uncertainty. Perceived uncertainty is defined as "an individual's perceived inability to predict something accurately" (MILLIKEN 1987, p. 136). Therefore, actors perceive environments in different ways, which are determinant to their behavior. Perceived uncertainty about the environment can be categorized into three types: state uncertainty or perceived environmental uncertainty; effect uncertainty; and response uncertainty.

The state uncertainty relates to the inability to predict the future state of the organizational environment or a particular component of that environment. "Uncertainty about the state of the environment means that one does not understand how components of the environment might be changing" (MILLIKEN, 1987, p. 136), as for example uncertainty of what actions relevant organizations may take or uncertainty about nature of general changes in state.

The second uncertainty, effect uncertainty, is the inability of decision makers to predict how environmental events will impact their organizations. It depends, thus, on the conditions of the organization's external environment. "If state uncertainty involves uncertainty about the

future state of the world, then effect uncertainty involves uncertainty about the implications of a given state of events in terms of its likely impact on the organization's ability to function in that future state" (MILLIKEN, 1987, p. 137).

Lastly, the response uncertainty concerns the inability of managers to identify available organizational actions and their outcomes, as to choose the best response to a specific change. "This type of uncertainty is experienced in the context of a need to make an immediate decision" (MILLIKEN, 1987, p. 138).

It is interesting to highlight that although the innovation literature acknowledges the importance of uncertainty, the concept is still not well elaborated in studies concerning innovation. "While the course of technological change is widely accepted to be highly uncertain and unpredictable, little work has identified or studied the ultimate sources and causes of that uncertainty" (FLEMING, 2001, p. 117).

An interesting approach concerning the link between uncertainty and innovation decisions is the one presented by Meijer et al. (2006). Based on an extensive literature review and previous empirical work, they propose a framework for perceived uncertainties involved in innovation decisions under socio-technological transformations. Considering the previous work of Milliken (1987) about different sources of uncertainties and the importance of distinguishing them in order to choose the most appropriate strategies and taking into account different views from other authors, Meijer et al. (2006) focus on uncertainties present in organizational decision-making dealing with innovation projects.

Table 1 - Sources of perceived uncertainty with respect to innovation decisions

Sources of perceived uncertainty with respect to innovation decisions.

Uncertainty source	Description
Technological uncertainty	Uncertainty about the characteristics of the new technology (such as costs or performance), about the relation between the new technology and the technical infrastructure in which the technology is embedded (uncertainty to what extent adaptations to the infrastructure are needed), and about the possibility of choosing alternative (future) technological options.
Resource uncertainty	Uncertainty about the amount and availability of raw material, human and financial resources needed for the innovation, and uncertainty about how to organize the innovation process (e.g. in-house or external R&D, technology transfer, education of personnel). Resource uncertainty resides at the level of the individual firm, as well as at the level of the innovation system.
Competitive uncertainty	Uncertainty about the behavior of (potential or actual) competitors and the effects of this behavior.
Supplier uncertainty	Uncertainty about the actions of suppliers (i.e. uncertainty about the reliability of the supplier), whether the supplier will live up to agreements about the timing, quality, and price of the delivery. Supplier uncertainty becomes increasingly important when the dependence on a supplier is high.
Consumer uncertainty	Uncertainty about consumers' preferences with respect to the new technology, about the compatibility of the new technology with consumers' characteristics, and, in general, uncertainty about the long-term development of the demand over time.
Political uncertainty	Uncertainty about governmental behavior, regimes, and policies, ambiguity in interpretation of current policy or a lack of policy and unpredictability of governmental behavior.

Source: Meijer et al. (2010, p.1224)

Meijer et al. (2006; 2010) present a framework with different sources of uncertainties, considering both the adoption and the development of innovations that are discussed in innovation studies and organizational management literature. The sources of uncertainties presented are: technological uncertainty; resource uncertainty (including uncertainty regarding labor and capital markets); competitive uncertainty; supplier uncertainty; consumer uncertainty (also known as market uncertainty); and political uncertainty (also called regulatory uncertainty or policy uncertainty). The description of each source of uncertainty is presented in *Table 1*.

It is also important to consider the effects of uncertainties on innovative entrepreneurship actions. "Uncertainty is an important factor that can perpetuate damaging behavioral tendencies due to sunk-costs effects" (ZELLNER, 2008, p. 441).

The presence of many uncertainties may be a major barrier to the breakthrough of new business and can retain the development and implementation of entrepreneurial activities (MEIJER et al., 2006). Studying further the presence of uncertainties in a specific area of business is therefore an important step towards a better understanding of their possible entrepreneurial activities.

3.6.3 The systematic literature review: uncertainties in the recycling of electronics

Taking into account the lack of further studies and the strong impact that uncertainties have in entrepreneurship, this part explores the main uncertainties present on the electronic waste recycling business. A systematic literature search has been conducted at the intersection of e-waste and uncertainty and the main uncertainties identified have been categorized according to the different types of uncertainty proposed by Meijer et al. (2006; 2007; 2010).

The search was conducted in the *Web of Science* website between 2014 August, 25th and 28th with the linkage between the exact words *e-waste*, *WEEE*, *waste electrical and electronic equipment* or *electronic waste*; and *uncertainty*, *uncertainties* or *uncertain*. The search has resulted in 39 articles, of which a search for the previously highlighted words has been made, in order to analyse their context. After this general analysis, 22 articles have been excluded from further reading, as they were not related to the subject. Therefore, 17 articles have been fully read and analysed.

The uncertainties discussed in the articles are categorized as follows in technological, resource, competitive, supplier, consumer and political uncertainty, just as proposed by the framework from Meijer et al. (2006; 2007; 2010). Nevertheless, there are different views on

how uncertainty is defined according to different authors. It is important to take into consideration that some of the uncertainties further categorized may not be according to the definition of uncertainty presented by some of the original scholars on the field, like Knight for example. Instead, they represent the different perceptions of uncertainty from the point of view of the authors analysed.

Technological uncertainty:

Berkhout and Hertin (2004) argue that the relationship between information technologies and environmental sustainability is very uncertain and complex, with many specific problems of resource use, emissions and waste management. Hung et al. (2013) also state that there are difficulties in accounting the WEEE emissions during disassembly and disposal.

As electronics have many different elements in their composition, including a substantial fraction of the periodic table elements, they can be considered as one of the most complex waste streams. It is also important to mention the different recycling technologies existent (BERTRAM et al., 2002).

Resource uncertainty:

As most of the forward production activities are not suited to deal with product movement in the opposite way, the reverse logistics costs are usually higher than the forward production system and difficult to estimate (ASSAVAPOKEE; WONGTHATSANEKORN, 2012).

Bertram et al. (2002) also state that, although it is possible to recycle up to 90% of the WEEE, the cost for this process is usually higher than the value of the recovered material and, as different processes may be applied, the recycling costs may vary.

Competitive uncertainty:

The WEEE rapidly changing nature is very relevant, which results in difficulty of establishing an adequate waste treatment facility (BERTRAM et al., 2002).

Supplier uncertainty:

Assavapokee and Wongthatsanekorn (2012) state that the return flow of end-of-life electronics is not a demand-drive flow like in the forward production system, but a supply-

driven flow, which has a very high level of uncertainty of return items concerning quantity, quality and timing. Chen et al. (2012) and Phuc et al. (2013) also mention those three aspects. Xanthopoulos and Iakovoup (2009) talk about the uncertainty regarding the quality level of returned products as well.

Gregory et al. (2007) and Bertram et al. (2002) also mention the uncertainty of collection rates. "Part of the uncertainty is caused by the fact that there is no information about the amount of old appliances stockpiled in households" (VYZINKAROVA; BRUNNER, 2013, p.905).

The electronics' life span also is an uncertainty, as stated by Kim et al. (2013, p.942):

> Estimates are usually based on domestic demand for electronic devices and their average life span (i.e., the length of the time between the initial purchase of an electronic device and the time it completes its useful life). Life spans vary depending upon the type of device, economic and market conditions, age, and cultural behavior.

Gregory et al. (2009, p.5) state that "studies on the age of e-waste returned for recycling have indicated that there is a wide distribution in the product lifespan". In this sense, it is very difficult to predict the amount and frequency of WEEE. Habib et al. (2013) also affirm that there is uncertainty of future supply and demand of recycled materials, mentioning the international markets.

Kahhat and Williams (2012) affirm that there is a lack of knowledge about end-of-life electronics fate from individual and institutional users. Among the choices for disposition, the authors mention the flow from intermediary sector to landfill, recycling and exportation. Ogunseitan (2013) also mention the uncertainty about the ultimate environmental fate of electronics.

<u>Consumer/market uncertainty:</u>

Brown-West et al. (2010) mention the different value of scrap materials on the secondary commodities market, affecting the recycling value of products.

Competition between the manufacturer and the remanufacturer is also present. In this sense, inter-firm relationship is very important to ensure stakeholders investments evaluation (KOH et al., 2012).

Further, "due to the inherent uncertainty and variability in product returns, no company can exclusively rely on filling the demand for new products from remanufactured ones" (XANTHOPOULOS; IAKOVOUP, 2009, p.1704).

Political/regulatory uncertainty:

Brown-West et al. (2010) affirm that although legislators see the e-waste regulation as very important to environmental thinking, the legislation is not uniform at the national and at the global level. Further, financial and collection schemes vary, with complex and sometimes outdated regulations.

"The disharmony between policies and procedures to regulate and manage e-waste can be linked to the differences in weights assigned to uncertainties in risk analysis among decision makers" (OGUNSEITAN, 2013, p.313).

Taking into consideration all the aspects mentioned during the systematic literature review, *Table 2* summarizes the main aspects concerning uncertainties in the e-waste recycling business.

Table 2 - Uncertainties in the e-waste recycling business

Uncertainty Source	**Description**
Technological uncertainty	Different recycling technologies; Unknown environmental impacts; Different product design and composition.
Resource uncertainty	Unknown reverse logistics costs; Variable cost of recycling.
Competitive uncertainty	Rapidly changing nature of electronics.
Supplier uncertainty	Unpredictability about return of items concerning quantity, quality and timing; Unknown destination of WEEE.
Consumer/market uncertainty	Different value of scrap materials; Competition between the manufacturer and the remanufacturer.
Political/regulatory uncertainty	No common legislation at the national and global level; Outdated political aspects; Complexity of regulations.

Source: Developed by the author

3.7 Discussion about the literature review

The part of literature review has the main aim of discussing the main concepts and stablishing the conceptual framework for the research. It represents a way of building a foundation for a proper understanding of the next chapters, more specifically *The European scenario*, the *Institutional and legal aspects for the management of electronic waste in Brazil* and the case studies dealing with the *Companies' strategies towards the recycling of electronics*. It brings a variety of different concepts, as result of the high complexity in which the recycling of electronic waste is involved.

By the common understanding that Production Engineering deals with the management of integrated production systems, it is clear the relation between this specific engineering and sustainability issues. With integrated systems of machines, men, materials, energy and the environment, it is indispensable that such production systems are build and applied aligned with the ideas of sustainable development.

When dealing with the systems for production of electronics, it is indispensable to take into consideration theirs impacts after the end-of-life. In this sense, the first subjects of the literature review are *Green economy and sustainable development* and *Circular economy*. Although different, such subjects are strongly interconnected. With the scarce resources and the quest for more sustainable ways of production and consumption, the concepts of green and circular economy become everyday more relevant. As both of them worry about the three pillars of sustainable development, namely the social, environmental and economic ones, both the green and circular economy have been identified as some of the main concepts that should be well-grounded when working in the particular subject of electronics' recycling.

Already appearing in the late 1980 as discussed in the literature review, the ideas of green economy are not very new, just as the ideals of attending both the economic and social needs while at the same time taking into consideration the environmental aspects. Besides, it is interesting to mention the three improvements in policy areas highlighted as necessary to achieve a more sustainable economy, which are to value the environment, to account for the environment and the proper pricing of products and services.

The circular economy also presents a very interesting view on how production systems should be designed. Although there are many strong models dealing with decision making towards a sustainable development, the circular economy one is among the most powerful ones, as presented in the literature review. In addition, at it is discussed with detail in the chapter *The European scenario*, the concept of circular economy has been widely used in recent years.

The concept of circular economy, as discussed in the literature review, is also not new, being coined in 1966 as the long-term aim joining sustainability, zero waste and economic growth. Differently from the traditional linear system of production, the circular model has the basic idea of looking at the waste as a resource, which goes back into the system after the end-of-life, in order to close the loop for a sustainable system of production and consumption.

The next section of the literature review, *Electronic devices and electronic waste*, brings the specific topics of the definition and composition of the electronics, in addition to their environmental impacts and recycling process when achieving the end-of-life. Especially when dealing with the recycling process, as it is studied further in the research, it is indispensable to have in mind the different characteristics of this specific waste, which is extremely harmful to the environment when not dealt correctly and demands different approaches in comparison to the regular waste.

The following section talks about the *Reverse logistics of electronic waste*. An important part of the Production Engineering involves the logistics and, in the sense of environmentally friendly systems of production, the reverse logistics are of extreme importance. The reverse logistics may easily be connected with the circular model already mentioned, as they involve the flow process from the consumption to the origin, in order for the recycling process to occur.

More than that, the reverse logistics can be part of the company's strategy, which is also discussed in the subsequent section, the *Strategy for the reverse logistics and recycling of electronics*. By highlighting ideas from some of the main scholars in the field of strategy, this section makes clear that the company may perceive the subject of electronic waste as either a threat or an opportunity. In this sense, the recycling of electronic waste could be seen as an obligation for the companies, in order to obey laws, but it may also be perceived as a differential. By adopting such strategy, companies could see the recycling of electronics as a positive aspect, so that to differentiate themselves in the market as environmentally friendly companies, while at the same time profiting from the value of the residues.

All the subjects already mentioned in the literature review concerning electronics' recycling make clear that such process is highly complex, involving a variety of uncertainties. In this sense, the last section of the literature review is entitled *Innovation and uncertainties in the recycling of electronics*, bringing a systematic literature review of the main uncertainties identified in the electronic waste recycling business. From this, it is possible to evidence the variety of uncertainties in different sources of the chain, like supplier, regulatory and technological uncertainties. All these uncertainties identified make clear the many actors

involved in the process and the need of a multidimensional and joint approach for such systems to properly work.

It is important to mention that the concepts mentioned in the literature review, although may seem simple, involve a whole change of mentality when applied into practice for the recycling of electronic waste, making their implementation rather complex. It is not only the result of a collective approach, but also of a collective learning process, as it should evolve through time, focusing on the long run.

4 THE EUROPEAN SCENARIO

The current chapter brings the European scenario and is divided in four sections. The European Commission has a number of programmes towards a sustainable growth and some of these main programmes are studied further on the first section. Secondly, the situation towards electronic waste in Europe is presented. Thirdly, the European legislations towards electronic waste are analysed. The last section brings some discussion about the chapter.

4.1 The European Commission programmes towards a sustainable growth

With the need to create conditions to move beyond the crisis, heading to a more competitive economy, besides the growing concern for environmental issues and the need for more effective approaches, the European Commission started a new strategy in 2010. The Europe 2020 Strategy is the European Union's growth strategy for the coming decade, covering employment, education, research and development, climate/energy, social inclusion and poverty reduction as main targets.

The strategy is directly linked with sustainability aspects, as it sees the improvement in resource efficiency as the main aspect to securing growth for Europe, while improving productivity, boosting competitiveness and driving down costs. The Europe 2020 Strategy states in its website that, in order to achieve its goals, it is necessary "[…] to develop new products and services and find new ways to reduce inputs, minimise waste, improve management of resource stocks, change consumption patterns, optimise production processes, management and business methods, and improve logistics" (EC COM 21, 2011, p. 2).

The European Commission works with two flagship initiatives to improve a sustainable development. The first one is the *Resource-efficient Europe*, in which it promotes a more efficient use of resources and a low-carbon economy to work in direction of a sustainable growth. By this, not only environmental aspects would improve, but also productivity, competitiveness and economic opportunities (EC COM 21, 2011). The other flagship initiative, *an industrial policy for the globalization era*, is mainly a policy to encourage businesses that work according to sustainability principles. This second flagship is based on supporting entrepreneurship and on covering all parts of the value chain.

One of the initiatives from the Europe 2020 is the Online Resource Efficiency Platform (OREP). It fosters the improvement of resource efficiency, with the main aim of boosting competitiveness while maintaining a high quality of life for achieving a sustainable economy

in Europe until 2050. For that, it promotes a series of milestones to be followed until 2020, with the key resources seen from a value-chain and life cycle perspective.

According to OREP's website, "resource efficiency means using the Earth's limited resources in a sustainable manner while minimising impacts on the environment. It allows us […] to deliver greater value with less input". Its website also has an interactive library, working as a comprehensive tool that exchanges information among stakeholders interested in the subject of resource efficiency.

The Roadmap to a Resource Efficient Europe (EC COM 571, 2011) is one of Europe 2020 Strategy's main building blocks for the resource efficiency flagship initiative. It provides a framework of actions needed and ways to increase resource productivity, in order to transform Europe's economy into a sustainable one by 2050.

Concerning management of waste, EC COM 571 (2011, p. 7) points out to the high amounts of waste produced by the European Union:

> […] each year in the European Union we throw away 2.7 billion tonnes of waste, 98 million tonnes of which is hazardous. On average only 40% of our solid waste is re-used or recycled, the rest going to landfill or incineration.

The Roadmap also states that, although overall waste generation is stable in the European Union, the generation of some waste streams is increasing, like in the case of electronic waste.

The report (EC COM 571, 2011) highlights the need of facing waste as a resource. Considering the environmental aspects and the increasing value of raw material, much higher priority is needed for recycling and re-use. Especially for the European countries, this is an extremely relevant topic because raw materials are becoming more costly and harder to find, which is even more evident in the developed countries. A proper approach could lead to less dependence on imports of raw materials from other countries, making Europe less dependent on other economies. Further, it would open new opportunities for jobs and markets, improving each country's economy.

From the Roadmap to a Resource Efficient Europe published in 2011, the Commission launched in 2014 the Seventh General Union Environment Action Programme to 2020 (7th EAP), under the slogan - *Living well, within the limits of our planet*. The new programme gathers the main ideas of the Roadmap into a framework of actions to be taken with an integrated approach, according to different levels and areas of policies.

The priority objectives of the 7th EAP are as it follows:

> (a) to protect, conserve and enhance the Union's natural capital; (b) to turn the Union into a resource-efficient, green and competitive low-carbon economy; (c) to safeguard the Union's citizens from environment-related pressures and risks to health and well-being; (d) to maximise the benefits of Union environment legislation by improving implementation; (e) to improve the knowledge and evidence base for Union environment policy; (f) to secure investment for environment and climate policy and address environmental externalities; (g) to improve environmental integration and policy coherence; (h) to enhance the sustainability of the Union's cities; (i) to increase the Union's effectiveness in addressing international environmental and climate-related challenges (EC, 2014, p.10).

By analysing further some of the objectives of the programme (EC, 2014), objective (b) is directly linked with the *Resource-efficient Europe* flagship initiative. It should be addressed, according to the programme, as a Union's integrated industrial policy that establishes partnership between the Union, industries and member states. This objective also elucidates that some existing policy instruments are limited to production and consumption and that it is necessary to adopt further measures to improve the environmental performance of products and services in their entire life cycle.

According to objective (d), improving implementation of the programme should be given top priority, especially considering that the costs of failed implementation of legislation are estimated at around 50 billion euros per year. Hence:

> There is a need to equip those involved in implementing environment legislation at Union, national, regional and local levels with the knowledge, tools and capacity to improve the delivery of benefits from that legislation, and to improve the governance of the enforcement process (EC, 2014, p. 53).

It is also important to consider that there is a high level of complexity involved, as there are many differences within member states about the most appropriate ways of implementing these legislations.

The programme affirms that environmental protection concerns have been integrated to other policies as a requirement since 1997. Nevertheless, the progress has not yet been enough to reverse the negative trends. Therefore, objective (g) aims at adopting a more effective integration of environment-related topics with policies and more coherent approaches to them. The incorporation of green infrastructure into plans is pointed out as a way of restoring ecological connectivity (EC, 2014).

The population's density in the European Union is another concern. According to EC (2014), 80% of the Union's population will likely live in urban and suburban areas by 2020 and

the conditions of the urban environment will have an extremely important role in the quality of life of this population. It is important to notice that the environmental impacts go beyond physical limits, as the urban environment is directly connected to suburban and rural regions. Inappropriate waste management is quoted as one of the main environmental problems in most cities.

More generally, lack of coordination among administrative authorities acting at different territorial scales is identified as a major issue:

> […] sustainable development requires effective and efficient coordination between different levels of administration and across administrative boundaries and the systematic involvement of regional and local authorities in the planning, formulation and development of policies which have an impact on the quality of the urban environment (EC, 2014, p.75).

Therefore, objective (h) suggests an *urban development network*, involving public and stakeholders in the decisions as a measure to ensure that a sustainable development is achievable.

Objective (i) states that a sustainable use of resources is one of the biggest challenges that the world faces today and that it is vital to ensure such use to be able to have a sustainable future. Rio+20 is pointed out as a key event that has gathered world leaders to discuss about actions in direction to this sustainable system for future generations, by adopting green economy and inclusive approaches to achieve this goal (EC, 2014).

The Environment Action Programme to 2020 gives a special focus on the circular economy model, in which the natural resources are managed in a sustainable way and the biodiversity is restored, enhancing therefore ecological resilience. Further, it points out to the importance of urgent and concerted actions to be taken in order to maximize the benefits that environmental policies can bring to the society and economy, while contributing to a better ecological resilience and respecting the planet's limits.

The programme also states that it is necessary to implement waste legislation in the whole Union, covering the different types and according to waste hierarchy. Concerning hazardous waste, which is the case of electronic waste, EC (2014, p.40) points out:

> Hazardous waste will need to be managed so as to minimise significant adverse effects on human health and the environment, as agreed at Rio+20. To achieve that aim, market-based instruments and other measures that privilege prevention, recycling and re-use should be applied much more systematically throughout the Union, including extended producer

> responsibility, while the development of non-toxic material cycles should be supported.

It also addresses public information campaigns as being an important tool for building awareness in the population towards the need to change behavior and obtaining knowledge of the waste policies.

Along with the Seventh General Union Environment Action Programme to 2020 is the Circular Economy package, directly linked with what has been previously discussed in the literature review. The EC COM 398 (2014), approved on 02 July 2014, promotes a transition from the linear economy, where resources are extracted and thrown away, to a circular one, where they are put back in the loop after being used.

According to the EC COM 398 (2014), improvements in resource efficiency along the value chain could reduce the need of input by up to 24% until 2030 and, by changing the use of these resources, up to 630 billion euros per year for the European industry could be saved. It is very clear that a more resource-efficient system can be positive not only for the environment, but also for the economy, when considered the financial and business aspect, if implemented properly:

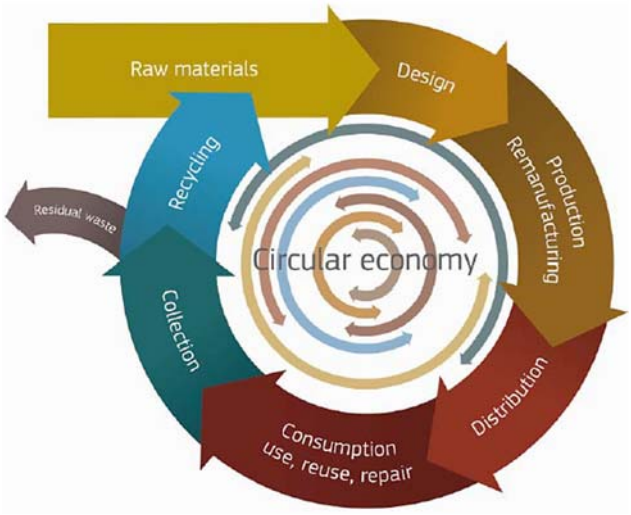
> Moving towards a more circular economy is essential to deliver the resource efficiency agenda established under the Europe 2020 Strategy for smart, sustainable and inclusive growth. Higher and sustained improvements of resource efficiency performance are within reach and can bring major economic benefits (EC COM 398, 2014, p. 2).

The package points out measures to drive a more efficient use of resources together with waste minimization. Many of the difficulties underlying the shift from the linear to the circular model are due to already existing business models, infrastructure, technology and established behavior. Most of the times the conventional habits represent a barrier for changing patterns, especially because of making the circular model appearing to be highly risky and complex. Therefore, one of the goals of the European Commission is to develop a framework to promote the circular economy along with stakeholders, based on a combination of measures such as "smart regulation, market-based instruments, research and innovation, incentives, information exchange and support for voluntary approaches" (EC COM 398, 2014, p. 4).

According to EC COM 398 (2014), the main phases of the circular economy model are: raw materials; design; production or remanufacturing; distribution; consumption, use, reuse or repair; collection; and recycling to complete the loop, with the least possible residual waste being generated. Hence, the recycling phase would be the last option in the system, as priority

is given to the phases like reuse and repair, which bring fewer damages to the environment than recycling. The main phases of the circular economy are represented in *Figure 9*.

Figure 9 - Main phases of a circular economy model



Source: EC COM 398 (2014, p.5)

The circular model proposed by the European Commission (EC COM 398, 2014) reinforces the need of a *design out* waste, so that the innovation occurs all across the value chain, rather than only at the end-of-life phase. The phases of the model are all interlinked and aimed at minimizing the escape of resources throughout the value chain. All phases work as a circle, one followed by the other. It is possible to conclude that, in an ideal system, the recycling phase would not be as necessary as it is today. Considering that all other phases, like the design of products, are implemented in a proper manner, the amount of waste generated for the recycling phase would be much less than in the current system:

> The European Union has set out its political commitment to reduce waste generation, to recycle waste into a major, reliable source of raw materials for the Union, to recover energy only from non-recyclable materials and to virtually eliminate landfilling (EC COM 398, 2014, p.8).

The idea of *turning waste into a resource* summarizes the circular economy system, especially by closing the loop. It is important to mention that approximately five tonnes of waste in the European Union is generated per year per person and, from this rate, only more than a third is recycled (EC COM 398, 2014). Much more than the programmes proposed by the European Commission, the objectives set by European legislation represent crucial tools for the

waste management to be improved. Furthermore, such waste policies could be one of the drivers to create jobs and to improve growth, without harming the environment.

EC COM 398 (2014) also has a chapter to tackle specific waste challenges. For hazardous waste, which is the case of WEEE, it states that data about the treatment path is still missing for part of this waste category. Therefore, a first action to take is to strengthen traceability by developing a proper registry system for the hazardous waste and to try identifying bottlenecks.

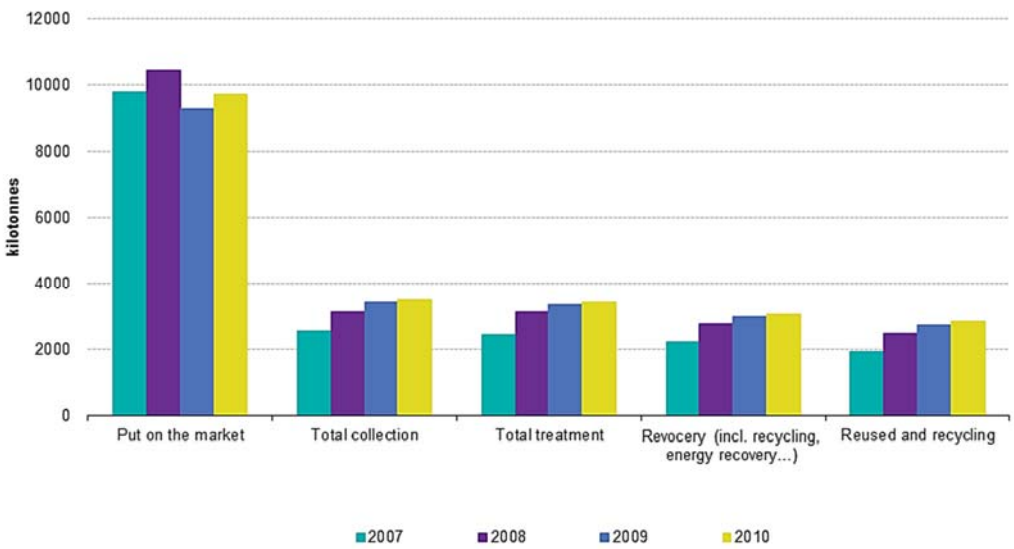
In sum, there is a strong commitment of the European Commission in favoring a new legislative and policy approach for the implementation of a new environmentally friendly and economically efficient model for production and consumption processes, and specifically by facing waste management problems along the whole value chain. However, one key difficulty lies in changing established behaviors and making the various stakeholders converge to a shared vision on environmental challenges and the constraints and costs they entail, but also on the economic opportunities they offer.

4.2 The situation towards electronic waste in Europe

As it has been possible to see in the previous section about the European scenario, Europe has a growing and considerable concern towards a sustainable growth, with a series of measures taken to address the issue of electronic waste management. Nevertheless, even in Europe the situation concerning electronic waste still has a lot to be improved.

As it may be observed in *Graph 1*, the Electrical and Electronic Equipment (EEE) put on the market by the European Economic Area (EEA) countries far exceed the Waste Electrical and Electronic Equipment (WEEE) collected and treated between the years of 2007 and 2010.

Graph 1 - EEE put on the market and WEEE collected in the EEA



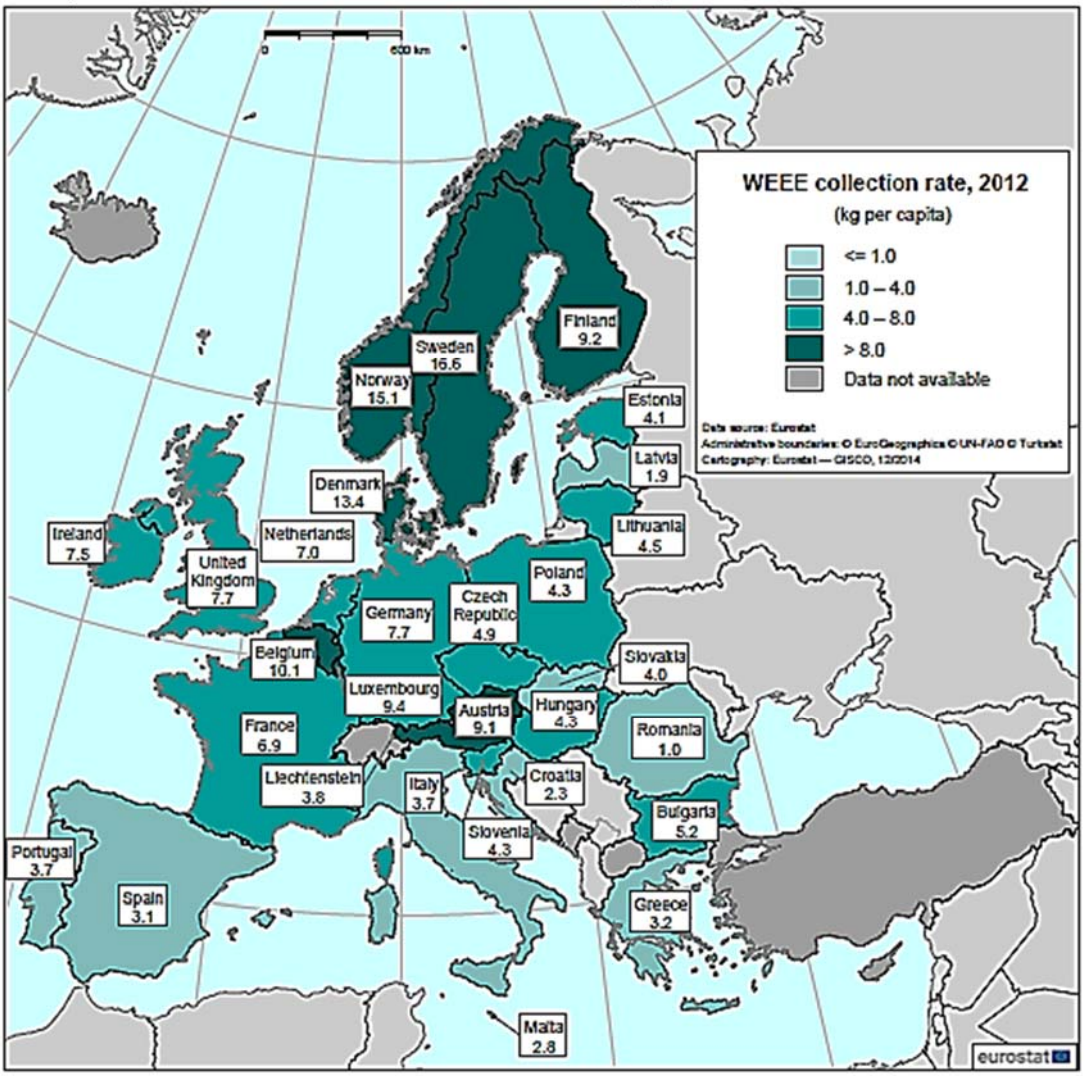
Source: Eurostat (2013)

Concerning the scenario in every country, *Figure 10* presents the collection rate in kg per capita of Waste Electrical and Electronic Equipment in 2012 for each country in the European Economic Area. According to EPA (2012), the European Union's Directive requires that at least 4kg per capita per year of e-waste should be collected in the European countries.

It is possible to identify that Sweden far exceeds the goal of the European Union's Directive. As it is possible to identify in *Figure 10*, it has the best recovery system from the material efficiency point of view, with 16.6 kg per capita of Waste Electrical and Electronic Equipment collected in 2012. Followed by Norway, with 15.1 kg and Denmark, with 13.4 kg, these three countries show evidently higher collection rates than the other countries in the European Economic Area. Nevertheless, some European countries do not yet collect the 4kg per capita, such as Spain, Italy and Greece (Eurostat, 2012).

According to The World Bank (2012), Europe represents an example of pioneer achievement in semi-precious processing in large scale. There are only four large integrated smelters and refineries processing precious metals worldwide, of which three are located in Europe. More specifically, The World Bank (2012) states that there is Umicore in Hoboken, Belgium; Norddeutsche Affinerie in Hamburg, Germany and Boliden in Rönnskär, Sweden.

Figure 10 - Waste Electrical and Electronic Equipment collection rates in 2012

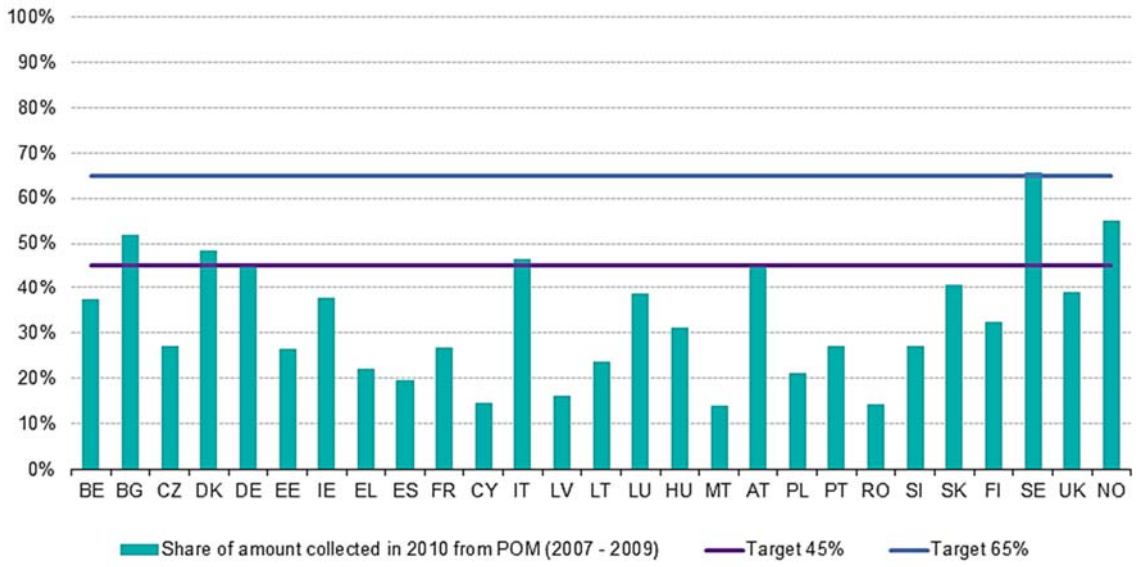


Source: Eurostat (2012)

Sweden represents the best example within the European Economic Area not only in absolute collection rates. When analysing the electronic recycling systems, it is important to also consider that the efficiency in the process depends not only on the absolute quantity of electronics collected and recycled, but also on the relation between this data and the electronics produced and put on the market.

Therefore, *Graph 2* brings the collection rates for Waste Electrical and Electronic Equipment in 2010 as a percentage of the average weight of Electrical and Electronic Equipment put on the market in the three preceding years (2007 - 2009), within the countries in the European Economic Area. It is possible to observe that Sweden not only is in the forefront in absolute collection and recycling terms, but also when looked by this different perspective.

Graph 2 - Collection rate for WEEE in 2010 as a percentage of the average weight of EEE put on the market in the three preceding years in the EEA countries



Source: Eurostat (2013)

4.3 The European legislations towards electronic waste

As it has been identified in the first section of the present chapter, the European Commission has a serious engagement with programmes to foster a sustainable economy in Europe. In this context, the Electrical and Electronic Equipment plays a fundamental role. Representing a worldwide problem nowadays, the electronics have a lot to be improved also in the European scenario, as pointed out in the previous section.

Therefore, many are the aspects that underpin the need of a good framework to deal with the electronic waste management. In the European scenario, the European Union has put into practice two pieces of legislation to deal with Waste Electrical and Electronic Equipment, which are the WEEE Directive and the RoHS Directive, both to be applied by all European Member States.

The first WEEE Directive was approved in January 2003 and entered into force in February 2003 as the WEEE Directive 2002/96/EC, as stated on the European Commission website about environment (EC WEEE Legislation, 2015). This has been the first framework established by the European Commission to collect the electronic waste free of charge from the consumers.

According to The World Bank (2012, p.7), the key aims of the Directive are to:

> Reduce e-waste disposal to landfill. Improve product design. Achieve targets for recovery, reuse and recycling. Establishment of collection facilities and separate collection systems. Implementation and financing by producers of systems for the recovery and treatment of e-waste.

The WEEE Directive has later had updated versions, the most recently one being the Directive 2012/19/EU, proposed in December 2008 and entered into force on 13 August 2012. The first version from 2002 was repealed on 15 February 2014, as the new Directive from 2012 was transposed into national law and is now effective.

The WEEE Directive is based on the principle of extended producer responsibility, that is, it imposes that producers are responsible for properly disposing the products that they put into the market at the end-of-life cycle. It has also settled a collection target for the member states of 4 kg per inhabitant per year. According to EC WEEE Legislation (2015), the most updated version of the Directive has, as one of its main goals, to tackle the fast increase of the electronic waste stream.

The other legislation towards the e-waste subject is the Restriction of Certain Hazardous Substances (RoHS) Directive. The first RoHS Directive is the 2002/95/EC, which entered into force in February 2003 and established that the producers must phase out some of the most hazardous substances (EPA, 2013).

According to the EC RoHS Legislation (2015), heavy metals such as mercury, cadmium, lead and hexavalent chromium and flame retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) should not be used anymore in the production of electronics and should be replaced by safer alternatives. According to ABDI (2013), the RoHs Directive also establishes that, except for some products such as batteries and specific industrial instruments, the highest concentration of these substances allowed by homogenous material weight is 1,000 ppm (parts per million). For Cadmium, the allowed concentration is lower, 100 ppm.

A revised version of the RoHS Directive 2002/95/EC was proposed by the European Commission in December 2008 and became effective on 3 January 2013 as the RoHS recast Directive 2011/65/EU (EC RoHS Legislation, 2015).

4.4 Discussion about the European scenario

By analysing the European scenario, it has been possible to identify a number of programmes organized by the European Commission with the aim of fostering sustainable growth practices within the European countries.

One of the main programmes identified is *The Europe 2020 Strategy*, which represents the European Union's growth strategy for the coming decade, fostering the improvement of resource efficiency, with the main aim of boosting competitiveness while maintaining a high quality of life for achieving a sustainable economy in Europe until 2050. The other programme, called the *Seventh General Union Environment Action Programme to 2020* (7th EAP), is an updated version of the *Europe 2020 Strategy*, giving a special focus on the circular economy model.

The serious commitment from the European Union to establish sustainable practices is also translated into a legal framework when concerning the electronic waste. Among the main laws applied to all the European Member States upon the subject, there are the WEEE Directive and the RoHS Directive, both established in 2003. While the WEEE Directive is based on the principle of extended producer responsibility, the RoHS Directive establishes that some of the most hazardous substances must be phased out from the production of electronics.

The laws and frameworks from the European Union show to be very advanced in the global scenario, as well as the positive situation of the European processes for recycling e-waste if compared to other countries. From the collection rates analysed, Sweden has the best recovery system from the material efficiency point of view, with 16.6 kg per capita collected in 2012. Nevertheless, it is important to have in mind that there is a lot to be improved even in the European scenario. For example, while the WEEE Directive establishes that at least 4kg per inhabitant per year of e-waste should be collected within the member states, many European countries still do not reach such target.

5 INSTITUTIONAL AND LEGAL ASPECTS FOR THE MANAGEMENT OF ELECTRONIC WASTE IN BRAZIL: A STUDY BASED ON SECONDARY DATA ANALYSIS

The current chapter brings some of the institutional and legal aspects for the management of electronic waste in Brazil. Based on secondary data analysis, it is divided in four sections. The first section presents the electronic waste scenario in Brazil. The legal framework for the management of electronic waste in the country is explained in the second section. Thirdly, there is the identification of the main actors involved in the recycling of electronics in Brazil. The last section brings some discussion about the chapter.

5.1 Electronic waste scenario in Brazil

Brazil is a wide country full of natural resources and is one of the fastest growing economies in the world. Nevertheless, it has a lot of challenges concerning planning and development as an emerging market. Together with the increase of population density in the urban areas, the urban problems have come along, especially in the big cities like São Paulo and Rio de Janeiro.

The waste increase and the lack of waste treatment is one of the major environmental challenges the country faces. It is very common the presence of open-air dumps, which are considered the worst way of waste destination, having no treatment and polluting the soil and the atmosphere, besides all the health problems it causes in the population living nearby.

The problem of waste is generalized in Brazil. According to the National Geographic Brasil (2013), about 58% of the waste produced in the country goes to sanitary landfills, while about 24.2% goes to controlled landfills and 17.8% still goes to open-air dumps. Considering that even the regular waste is often not treated in a proper manner, it is evident that with electronic waste, which is highly more complex, the situation is not at all better. A lot of e-waste is improperly disposed as household waste or stored in the Brazilian homes.

Brazil has the fifth biggest global electronic and IT market, being after China, United States, Japan and Russia. In addition, the Brazilian electronic and electrical industry contributes to 3.5% of the GNP and is rapidly growing. The ABINEE's membership, which is the Brazilian Electrical and Electronics Industry Association and represents more than 90% of this industry sector, had a growth of 11% of revenues in 2010 (THE WORLD BANK, 2012).

According to FGV (2015), the annual research on the use of information technology showed that, while 75% of the population in Brazil has a computer, the percentage worldwide is 56. For this study, FGV considered as computer the desktops, notebooks and tablets. The research shows that there were about 152 million active computers in Brazil in 2015, which means that for every four habitants in the country, three had a computer. According to the same research, the estimation is that until the end of 2017 there will be one computer for every person in Brazil.

Figure 11 has been taken from the *E-waste World Map* (STEP, 2015) and shows the case of electronic waste in Brazil. The electronic waste generated per inhabitant in 2012 was 7.06 kg that, considering the high number of the Brazilian population, corresponds to 1,387.85 kilotonnes of electronic waste generated in the country in 2012.

Figure 11 - Overview of e-waste related information in Brazil

Brazil

Overview of e-waste related information

Subject	Unit	Year	Amount	Source
Population	(total inhabitants in million)	2012	196.53	IMF WEO
Purchasing Power*	(USD per Inhabitant)	2012	12,038.46	IMF WEO
EEE Put on Market*	(kg per inhabitant)	2012	10.53	UNU (Jaco Huisman)*
	(total in metric kilotonnes)	2012	2,069.09	UNU (Jaco Huisman)*
E-waste Generated*	(kg per inhabitant)	2012	7.06	UNU (Jaco Huisman)*
	(total in metric kilotonnes)	2012	1,387.85	UNU (Jaco Huisman)*

Source: STEP (2015)

5.2 Legal framework for the management of electronic waste in Brazil

When studying about regulations in Brazil for the management of electronic waste on a national level, it is possible to observe that there is not currently a specific regulation dealing only with the electronic waste in Brazil. Nevertheless, there is the law nº 12.305, approved in 2010 and called the *National Solid Waste Policy* (PNRS). This law gives responsibility not only to the public service, but also to the private sector and to the population for a properly management of the electronic waste (BRASIL, 2010). While the public sector is responsible

for presenting plans for a proper waste process, including enough technology and participatory initiatives with cooperatives, the companies are in charge of collecting this material and the population should participate in the selective waste collection, besides changing some habits for decreasing the waste generation.

On the articles 30 to 36 (chapter III, section II), the PNRS establishes a shared responsibility of manufacturers, importers, distributors and retailers for all the life cycle of the product, including the reverse logistics for the post-consumer products. According to article 33, the reverse logistics needs to be established by the already described actors, independently of the public service of urban sanitation, for the following products: batteries; tires; lubricating oils and their residues/packaging; fluorescent lamps, sodium and mercury vapor, and mixed lighting; electronic products and their components (BRASIL, 2010).

As described in article 3 (chapter II) of the PNRS (BRASIL, 2010), the term *reverse logistics* is understood as the:

> […] instrumento de desenvolvimento econômico e social caracterizado por um conjunto de ações, procedimentos e meios destinados a viabilizar a coleta e a restituição dos resíduos sólidos ao setor empresarial, para reaproveitamento, em seu ciclo ou em outros ciclos produtivos, ou outra destinação final ambientalmente adequada .[1]

In the same article, it is also explained the term *shared responsibility for the products' life cycle*:

> […] conjunto de atribuições individualizadas e encadeadas dos fabricantes, importadores, distribuidores e comerciantes, dos consumidores e dos titulares dos serviços públicos de limpeza urbana e de manejo dos resíduos sólidos, para minimizar o volume de resíduos sólidos e rejeitos gerados, bem como para reduzir os impactos causados à saúde humana e à qualidade ambiental decorrentes do ciclo de vida dos produtos […].[2]

From the definition of reverse logistics and the shared responsibility for the products' life cycle stated on the Brazilian law, it is easy to connect the ideas proposed in the law with the need of an institutional change and a collective learning proposed in the literature review

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[1] Author's translation: [...] tool of economic and social development characterized by a set of actions, procedures and means to enable the collection and recovery of the solid waste to the business sector, for reuse in its cycle or other production cycles, or other environmentally proper disposal.

[2] Author's translation: [...] set of individualized and chained attributions of manufacturers, importers, distributors and retailers, consumers and owners of urban sanitation public services and solid waste management, to minimize the volume of solid waste and rejects generated, besides reducing impacts caused to human health and environmental quality due to the product's life cycle [...]

towards a *Green economy and sustainable development*. The need of an integrated management of actions among the diverse actors is, thus, strongly present and is recognized by the Brazilian law. In fact, one of the principles highlighted by the law 12.305/2010 is of adopting a systematic view for the solid waste management, considering the environmental, cultural, social, economic, public health and technologic variables, besides the cooperation between the public and private sectors.

In line with some principles of the *Circular economy* model presented in the literature review and to the ideas from the European Commission concerning the circular economy package, the Brazilian law also establishes a priority order that should be followed with the solid waste management. The order, according to article 9, is: non-generation, reduction, reuse, recycling, solid waste treatment and environmentally proper final disposal of waste.

The PNRS gives special attention to the role of cooperatives and collectors in the waste management. In Brazil, especially when it comes to waste management and reverse logistics, the cooperatives and the waste collectors have a very important role. Nevertheless, they are usually composed of a population's portion with low income that faces extremely vulnerable situations. Looked both from a social and economic sphere, they suffer from numerous deficiencies, resulting in prejudice, marginalization and exclusion of such individuals from the rest of the society.

According to article 18 of the PNRS (BRASIL, 2010), the municipalities implementing the selective waste collection in partnership with cooperatives or other kind of associations that work with collectors of reusable and recyclable materials composed by low income individuals should have priority in the access to the federal funds. Evidently, this insertion should be made together with training programmes, especially when it comes to a highly complex waste that demands specific knowledge in disassembling, like the case of the electronic waste.

The article 37 of PNRS (BRASIL, 2010) states that the installation and the operation of any project or activity that operates or generates hazardous waste, which is the case of electronic waste, may only be authorized by the authorities in charge if they prove the necessary conditions, besides economic and technical capacity to manage their waste at the end-of-life. Article 38 further discusses the issue, by instructing that all corporations operating with such hazardous waste, independently of the scale in the product's life cycle, are obliged to register at the *National Registry of Hazardous Waste Operators*, which is coordinated by a specific federal agency, jointly with the federal, state and local authorities.

The *National Registry of Hazardous Waste Operators* should serve as an information tool for the *National System of Information on Solid Waste Management* (SINIR). The SINIR

is supposed to work under the coordination of the Ministry of the Environment and should be organized and maintained by the federal government, the states, the federal district and the municipalities in a joint approach. The system should contain especially information from the states, the federal district and the municipalities. Its goal is to collect data relative to the public and private services of solid waste management, in order to make it possible to monitor and evaluate the efficiency in the process, analyse results and measure impacts.

It is interesting to comment that, although the *National Solid Waste Policy* was only approved in 2010, some other states approved specific laws at the state level to deal with electronic waste before the PNRS appeared. It is the case of the state of São Paulo, which has a specific law for the electronic waste management and recycling since 2009, n°13.576.

> Since much of the Brazilian electrical/electronic market is concentrated in this state, the prior existence of the state law will help implementation of the federal law. It will encourage the electric-electronic industry to establish priority goals at the state level, and to develop best practices on wider implementation. (The World Bank, 2012, p. 20)

The Law 13.576 (2009) gives shared responsibility for the companies that produce, commercialize or import electronic products or components. The destination of the WEEE should be for recycling processes that may be either for the original or diverse purposes; the total or partial reuse practices of the technological products and components; and the final appropriate neutralization and disposal of the hazardous components in the electronic waste. Further, it gives responsibility to the companies that produce, commercialize or import electronic products to maintain collection points to receive the electronic waste discarded by the consumer.

The Law 13.576 (2009) also states that the electronic products and components that are commercialized in the state need to prominently indicate on the packaging a series of information. The following information should be stated for the consumers: warning that the products should not be discarded as regular waste; guidance on the collection points; address and telephone number of those responsible for the material disposal at the end-of-life; and warning about the existence of heavy metals or toxic substances from the product components.

The state of Rio Grande do Sul also already had laws concerning electronic waste before the institution of the PNRS in 2010. According to The World Bank (2012), already in 1992 it adopted a law concerning the selective waste collection. By 1997, it adopted a law providing specific regulations for the final destinations of products containing heavy metals, including the reverse logistics model. By 2009, a new law requiring that the electronic retailers provide proper

places for the collection of electronic waste was put into practice. The municipality of Curitiba, in Paraná, also already had specific legislation for the electronic waste management before the PNRS (ABDI, 2013).

Besides São Paulo and Rio Grande do Sul, other states have also mobilized to implement laws for solid waste management before the PNRS, but most of them did not address the specific subject of electronic waste. Nevertheless, some states have diverse initiatives that have been put into practice. Minas Gerais has been one of the first Brazilian states to worry about the electronic waste, imposing responsibility across all the producer chain and developing a project together with the Swiss State Secretariat for Economic Affairs (SECO). The state of Paraná also has a law that gives responsibility across all production chain, putting into practice the concept of reverse logistics. Rio de Janeiro has an initiative carried out by software companies, called *Reciclação* and *Assespro Rio*, which aims at raising awareness in the population about the importance of a proper disposal, in addition to collecting, rebuilding and donating electronics (THE WORLD BANK, 2012).

It is important to mention that, as stated by The World Bank (2012), some states in Brazil do not have any laws concerning even the solid waste in general, such as the case of Bahia. Other states, like Rio de Janeiro and Ceará, although have laws concerning solid waste, have outdated policies that do not apply the reverse logistics model of extended producer responsibility.

After the PNRS has been applied at the national level, states and municipalities that already had laws concerning the subject started to adapt their laws accordingly to the national law. While it is necessary a change of laws and processes from the various Brazilian states and municipalities, which can be highly complex and challenging, the previous laws contain important steps that may serve as incentives and help in the learning process for a wide national approach, if taken as a joint approach.

An important tool for the reverse logistics of electronics in Brazil is the NBR 16156 stablished in 2013 by the Brazilian Association of Technical Standards and entitled *Waste electrical and electronic equipment - Requirements for the activity of reverse manufacturing* (ABNT, 2013). The norm sets out requirements for environmental protection, in addition to security and health control when dealing with the hazardous waste.

The collection of electronic products may happen either by fixed locations or by temporary collection campaigns. As example of these campaigns, there are the discounts given in some specific periods when purchasing a new product, in exchange of the old one. The collection involves a series of regulations, both from who is collecting and from who is

donating. While the collection places need to have specific environmental license due to the presence of hazardous components, the customer needs to sign a term for the product's donation (ABDI, 2013).

Besides the collection points organized by the public initiative or the production companies, ABDI (2013) remarks that the retail business is also becoming more and more engaged. As it has direct contact with its customers, it has a positive advantage in comparison to the other initiatives. Nevertheless, the high costs involved with storage and the very specific regulation that has already been mentioned are just some of the hindrances it faces.

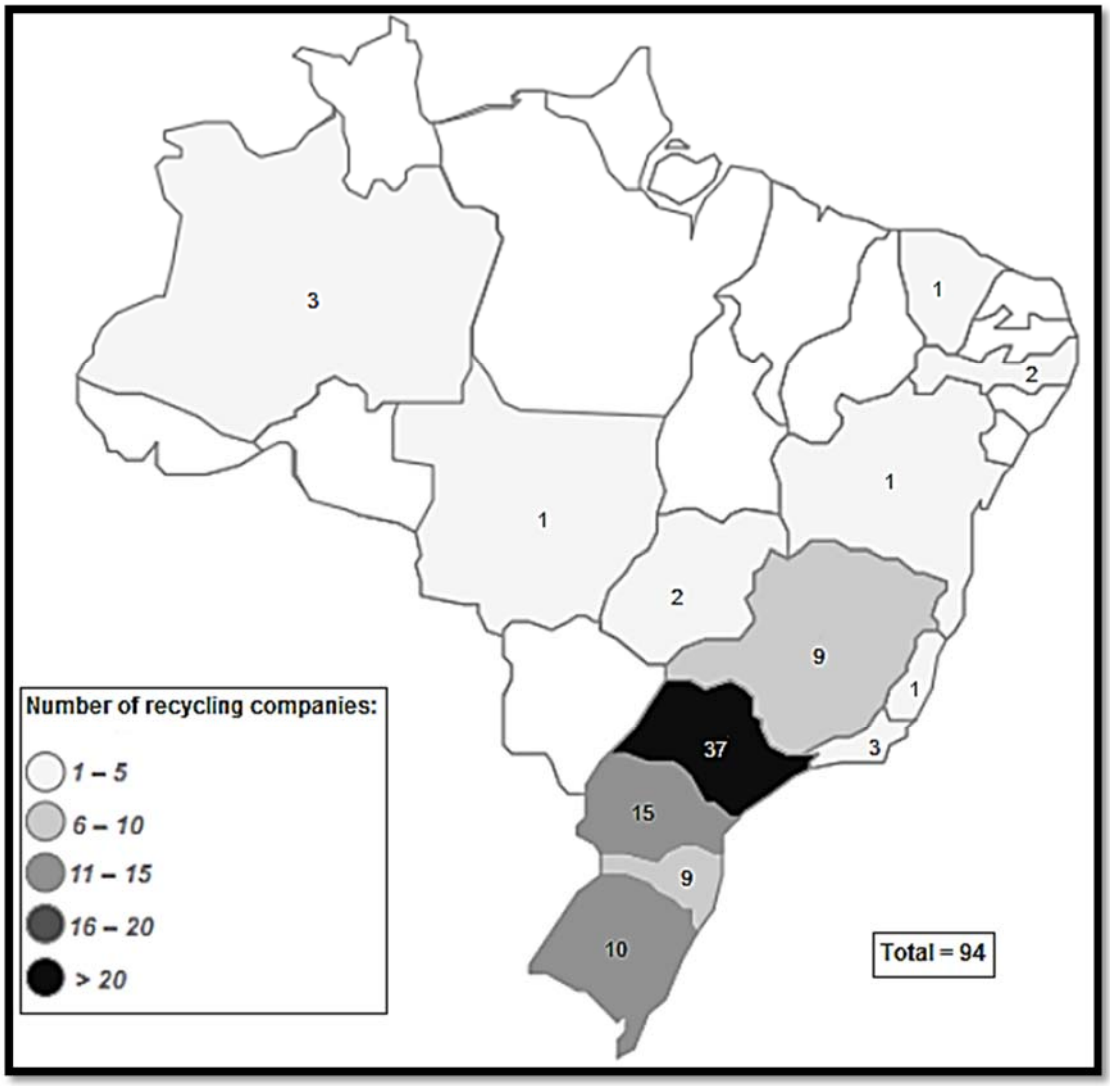
Another point of collection is the technical assistance shop. Motivated by the lower price of obtaining a new product than fixing the current ones, many customers end up by leaving their electronics in these places when they become aware of the costs involved. ABRASA (apud ABDI, 2013) mention that there are currently about 10,000 technical assistance shops in Brazil today. These places also face the other barriers mentioned, in addition to some specific regulations. The consumer protection law that requires that the product sent to repair remains for a certain period with these technical assistance shops is an example.

The recycling cooperatives have a very important role in the process in Brazil. ABDI (2013) mentions that it is estimated that there are about 600,000 collectors in the country. One of the main barriers for these professionals is the lack of knowledge about how to deal and redirect the electronic waste that, many times, ends up in the regular waste. The lack of infrastructure and proper equipment to do the process is also present, often even for the regular waste. ABDI (2013) also comments that recycling companies and the public service also have temporary initiatives to collect the electronic waste.

After the collection, the electronic waste is transported to recycling facilities. *Figure 12* shows the number of recycling companies of electronic waste in each Brazilian state, according to ABDI (2013). The state of São Paulo has the highest number for this specific waste, with 37 recycling companies of electronic waste. It is interesting to mention that the metropolitan area of São Paulo is, by far, the most populated metropolis in Brazil, as well as one of the most populated in the world.

The report comments that the recycling companies in *Figure 12* have diverse processes and that a considerable amount of WEEE generated is not recycled in Brazil, but instead exported for further treatment. In addition, the so-called *WEEE recycling companies* acting in the country have low efficiency when compared to the existing technologies of other countries. Some of these facilities stated in *Figure 12* only separate and grind the material, which is later exported to plants in Asia.

Figure 12 - WEEE recycling companies acting in Brazil



Source: Adapted from ABDI (2013, p.36)

It is important to consider that, as stated by ABDI (2013), when the electronic waste is transported from one state to another, the Brazilian law imposes the collection of taxes for this waste. This represents an enormous barrier in the process, considering the already expensive nature of the process, besides the large geographical dimensions of the country and the 26 states plus a federal district that it is composed of. “An e-waste system with an additional recycling fee seems to be very unpopular, as the Brazilian tax system already puts high burdens on producers and consumers” (UNEP, 2009, p. 65). The process is rather unstable, mainly due to the informal collection and the unpredictability in the material’s supply.

When arriving at the recycling companies that specifically work with electronics, the products are dismantled and redirected for the recycling process of each component. Nevertheless, although there are specialized recycling companies for the electronic waste, they do not hold enough technology to do the whole process. According to ABDI (2013), such companies work in a relatively small scale and cannot afford to invest in the technology needed to finish the recycling process. Therefore, the process is much less efficient than the European one and many components are exported to other countries.

While the separation and the grinding are done in Brazil, the circuit board is exported to other countries. The circuit board is the component that has the precious metals, like gold and others, being exported with a similar price as the rest of materials from electronic scrap. According to the *System of Analysis of Foreign Trade Information*, called AliceWeb (ABDI, 2013), more than 20,000 tonnes of waste that potentially came from electronic products were exported in 2011.

In face of the many difficulties in the recycling process, ABDI (2012) defends that the accessories should be standardized in Brazil, so that to facilitate the disassembly in the recycling process. Furthermore, it suggests that more spare parts should be made available to increase the lifespan of products and that companies should invest more in eco-design as a way to reduce the environmental impact of their products.

It is possible to observe from the secondary data analysis that Brazil has just recently started to plan approaches for the electronic waste management by moving a national legislation on solid waste in 2010. Although it has a legal framework on electronic waste that addresses many important topics, it does not have so far an effective systematic process of reverse logistics and recycling of electronic waste in practice.

As highlighted by The World Bank (2012), one of the challenges concerning e-waste is the gray market. This market comprises about 20% of mobiles in Brazil and negatively affect the process, besides being more difficult to comparatively measure the successful rates of collection and recycling with the production rates.

According to UNEP (2009), Brazil is among the countries that have the potential to implement both pre and some end-processing technologies of electronic waste recycling, together with an exchange of knowledge and technology. Brazil has evidently a long path to follow until achieving good collection rates such as the developed countries. Nevertheless, it may potentially develop its process to have a positive action in the global scenario, considering it is the biggest country in South America and has one of the biggest electronic market in the world.

5.3 Identification of the main actors involved in the recycling of electronics in Brazil

As it has been pointed out during the secondary data analysis, Brazil relies today on the national law PNRS to deal with the electronic waste management. Nevertheless, many municipalities and states have previously adopted legislation to deal with this specific waste stream and now are trying to adapt their legislations according to the national policy. In addition, the PNRS itself states that the process should be the result of a joint approach, in the public aspect, of the federal government with the Brazilian states, municipalities and federal district.

Figure 13 - Municipalities in Brazil

Source: Adapted from IBGE (2015)

Brazil is a very wide country, which results in a challenge when such a highly complex issue as the electronic waste needs to be managed as a joint approach. Brazil has 26 states and 1 federal district, which together represent 5,570 municipalities (IBGE, 2015). The highest municipality density is concentrated mainly on the Brazilian coast, especially in the South and Southeast region, as it may be observed in *Figure 13.*

The Ministry of Environment is responsible for coordinating the *National System of Information on Solid Waste Management* (SINIR), having as such a very important role. The distributors, importers, retail business and the technical assistance shops also have their importance in the process, especially concerning the reverse logistics of electronics.

With focus on the recycling process, the recycling cooperatives and the waste collectors also have an important role to play, as already discussed. In this sense, it is indispensable that both have enough qualification to deal with the electronics, in order for the process to be effective.

Another important role for the recycling of electronics belongs to the recycling companies that, as identified in the case study, are 94 in the country, with the highest number in the state of São Paulo. Another key aspect to consider about the electronic waste recycling companies is that, although already pointed out, they do not hold enough technology to do the whole process. Therefore, although with a crucial role in the recycling of electronics, the process from the recycling companies in Brazil is still incomplete.

There is a series of associations and entities moving efforts towards improving the recycling process of electronics in Brazil. Concerning the recycling of waste in general, it is worth mentioning the CEMPRE association that, according to its official website, is supported by private companies from diverse sectors and is dedicated to improving the recycling with an integrated waste management approach in the country. Focusing specifically in the electronics, there is the ABREE association, which is the Brazilian Association for Electronics and Home Appliances Recycling.

Still in relation to the associations, there are also ELETROS and ABINEE, both focusing on the manufacturers of electronics. ELETROS is the National Association of Electronic Products' Manufacturers, while ABINEE is the Brazilian Electrical and Electronics Industry Association. ABINEE actively participates in the process of electronics' recycling in Brazil, with special highlight to the sectoral agreements proposal as a way of enhancing the process in the country.

Lastly, it is important to consider the essential part of the manufacturers of electronics in the process of recycling. Just as in Europe, Brazil has established the extended producer

responsibility principles with the PNRS, as well as giving responsibility to the retailers of electronic products. Thus, all companies that work with electronics are responsible for providing a proper way of collecting this end-of-life product and give it an environmentally friendly final destination.

5.4 Discussion about the institutional and legal aspects for the management of electronic waste in Brazil

After analysing the institutional and legal aspects for the management of electronic waste in Brazil, it is possible to observe that the country has just recently increased its awareness about the electronic waste subject. With no specific regulation for the electronic waste at the national level, Brazil relies so far on the *National Solid Waste Policy* (PNRS) from 2010 to deal with the electronic waste at the national level. Although the PNRS has many positive and relevant points about the electronic waste management, it is important to emphasize that it is a considerably recent law.

Something to consider is what has been discussed in the literature review about the need of a collaborative approach in order to obtain a *Green economy and sustainable development* on the long run. From that, it is easily observable that Brazil has a long path to follow, so that to achieve a desirable level of collection and recycling of electronic waste. Further, it is important to have in mind that much of what is proposed by the PNRS, although ideally relevant, is not yet working in practice.

Another point to consider is that it appears to have a lack of collaborative approach among the municipalities, states and Federation. Many states have their own laws concerning the electronic waste disposal and recycling and now need to adapt their plans according to the national legislation. Although a national legislation shows to be an interesting approach to take, it is important to take into consideration the state laws already made about it, in order to achieve a high level of learning from each state. One example is the law from the state of São Paulo, stating relevant specifications about packaging information of electronics for future disposal, while in the national law nothing is mentioned about it.

It has been possible to identify many hindrances in the process. One of them is the need of qualifying the collectors to have enough knowledge when dealing with the electronic waste. With enough qualification, the process may be more effective and benefit not only the

environment, but also the collectors by improving their income with the price specifically for the electronic scrap.

Another barrier is the lack of infrastructure and technology. Although with high rates of e-waste production, the country is not yet capable of doing the entire recycling process and ends up in exporting the most complex components of the product, which has the precious metals, to other countries, for a much lower price than it is worth it. Therefore, the country must study about possibilities of implementing such process on national ground, so that it does not lose those valuable resources.

Lastly, there is the obstacle of the interstate taxes. The process of electronic waste is naturally expensive and, in order to be financially viable, it demands not only a high investment, but also high rates of materials. Therefore, the recycling process should be implemented in a large scale. With the many states in Brazil, it is evident that the e-waste transportation among different states is needed. With an already complex and expensive implementation, it does not seem logic for the companies that want to embrace an environmentally friendly process to be obliged to pay taxes for transporting the waste across the country.

Table 3 brings a summary of the main points identified about the institutional and legal aspects for the management of electronic waste in Brazil.

Table 3 - Institutional and legal aspects for the management of electronic waste in Brazil

Institutional and legal aspects for the management of electronic waste in Brazil	
EEE put on the market	10.53 kg per inhabitant in 2012 (STEP, 2015)
E-waste generated	7.06 kg per inhabitant in 2012 (STEP, 2015)
Is there a law towards e-waste management? Which one?	Yes. The National Solid Waste Policy - PNRS (from 2010) has some chapters addressing the e-waste subject.
Does the law establishes the extended producer responsibility?	Yes.
Main approach in the country towards the subject	Law at the national level establishing guidelines to work together with the municipalities.
Main actors identified in the case studies (not a complete tool for analysis)	5,570 municipalities; Ministry of Environment; 94 WEEE recycling companies; associations such as ABINEE, ABREE, ELETROS and CEMPRE; distributors; importers; retail business; the technical assistance shops, the waste collectors and the recycling cooperatives.
Main strengths identified	* The National Solid Waste Policy (PNRS) establishes many relevant points, representing an interesting legal framework for the management of e-waste in the country. * The norm ABNT NBR 16156 from 2013 sets out requirements for the reverse manufacturing activities of electronic waste.
Main weaknesses and uncertainties identified	* Just recently started to prepare legislation towards the recycling of electronics. * Lack of collectors' qualification for dealing with the WEEE. * Much of what is proposed by the PNRS is not yet working in practice. * There is not yet a specific body to manage the e-waste in the country. * Lack of collaborative approach among actors. * Interstate taxes for transporting the e-waste. * Lack of infrastructure and technology: The country is not yet capable of doing the entire recycling process. * A lot of e-waste still falls outside the system, with no knowledge about its treatment destinations and conditions. * A considerable quantity of WEEE is exported to other countries, especially the most complex components. * The population very often stores the devices after end-of-life. * Lack of population's awareness, with WEEE being many times discarded as regular waste.

Source: Developed by the author

6 COMPANIES' STRATEGIES TOWARDS THE RECYCLING OF ELECTRONICS: THE CASE STUDIES

The present chapter has special focus on the corporative side, with the main objective of understanding the current scenario of the electronic companies towards the recycling of electronic waste.

Taking into consideration the high rates of consumption and the trends for increase described in chapter five - *Institutional and legal aspects for the management of electronic waste in Brazil*, the main notebook manufactures are studied more specifically. The list of the ten major notebook manufacturers in Brazil (Tecnoblog, 2015) is as follows, in descending order of number of sales in the country: Positivo, Dell, Lenovo, Acer, Samsung, Asus, HP, Semp Toshiba, LG and Apple.

From this list, it has been possible to choose which companies to study further. As they are companies with the strongest presence in the Brazilian market of notebooks, it is believed that they are among the companies with the highest chances of having a proper infrastructure and enough actions to deal with the matter of recycling of their products in the country.

The chapter brings different approaches and, for this reason, it is divided in four sections. The first section analyses the websites of all the ten companies in Brazil, as a way to identify which actions towards recycling they have announced on their websites and how they communicate the public about their actions for collection of their end-of-life products in the country. Eight of the ten companies, which are present worldwide, are also analysed on their websites in the United Kingdom, as a way of comparing the actions of the same companies in the Brazilian and in the European scenario.

The second section brings the strategy of the *mysterious client*, in which the researcher contacts all the ten companies in Brazil, pretending to be a consumer wishing to discard its old notebook, so that to identify how the companies are dealing in practice with the issue of informing the public about their actions. The third section brings the interviews with the Brazilian Association for Electronics and Home Appliances Recycling (ABREE), two of the companies from the list and one recycling partner for another company from the list, as a way to understand further how they are dealing with the recycling of electronics from mainly a strategic and operational point of view. The last section brings some discussion about the chapter.

6.1 Website analysis

For the website analysis, the main objective is to identify whether and, in a positive case, how some of the electronic companies inform the public on their websites about their actions towards the collection of their products for recycling after the end-of-life. It is also aimed at identifying how they are dealing with social responsibility/sustainability issues on their websites.

The list of the ten major notebook manufacturers in Brazil has been the first step to decide which companies to analyse further, as a way of studying companies with strong structure and presence in the Brazilian market. From that on, all these companies' websites are further analysed.

The section is divided in two parts. The first part analyses the Brazilian websites of the ten companies, as a way to understand how such companies are dealing with the matter in the country. Connecting with chapter four - *The European scenario*, the second part of the current section has the aim of comparing the Brazilian with the European context in terms of information in the companies' websites. From the ten companies, eight are present worldwide. Taking into consideration the language constraints, the websites of the companies in the United Kingdom are analysed for the European context. As such, the second part brings an analysis of the eight companies in the United Kingdom and a comparison with the information given by the same companies in both countries, Brazil and the United Kingdom.

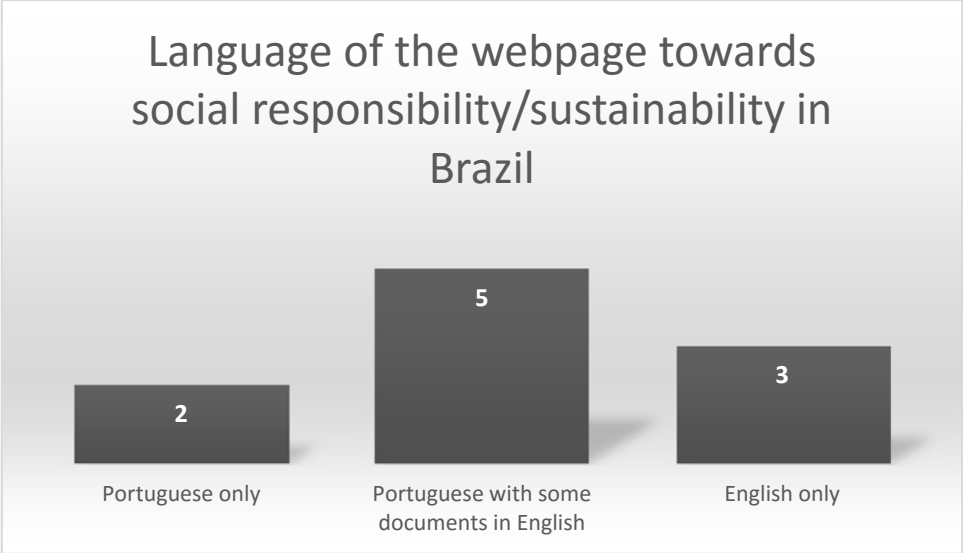
6.1.1 The Brazilian websites

After analysing all the companies' websites in Brazil, it has been possible to observe that all the ten companies have webpages with information dealing with social responsibility and sustainability issues. In pace with the growing concern for the importance of such issues on the business sphere, this shows commitment of such companies on informing the public about their actions.

Nevertheless, an important point to take into consideration concerning the information given about social responsibility and sustainability issues is the language in which such information is given. As it may be observed in *Graph 3*, three of the ten companies analysed have all the information towards this matter given only in English, even though they are Brazilian websites. Half of the companies have such pages in Portuguese, but with some

documents in English, like sustainability reports, documents about green initiatives and corporative policies. From all the companies, only two have all the information dealing with the subject in Portuguese, with the important highlight that these two are the only Brazilian companies from the list.

Graph 3 - Language of the webpage towards social responsibility/sustainability in Brazil

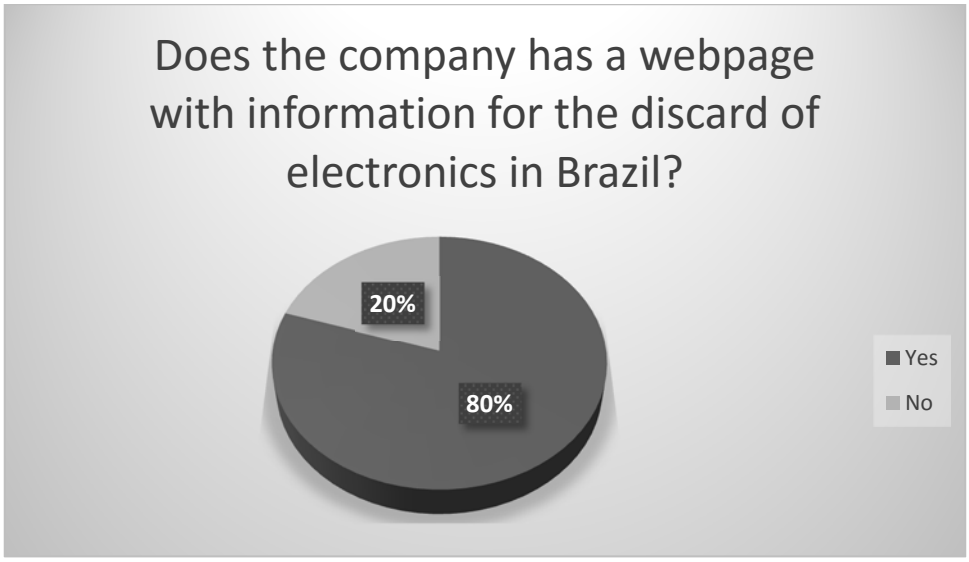


Source: Developed by the author

Considering that, although most of the companies are multinationals from other countries, these websites are directed to Brazilian customers and these companies are the ones with the strongest presence in Brazil, such information should be provided on the official and widely spoken language of the country they are operating in. Therefore, the lack of information in Portuguese represents a huge hindrance for a proper communication to the Brazilian population about this matter.

About the specific subject of electronics' collection for recycling, most companies have a webpage specifically for that. As it is shown in *Graph 4*, eight out of the ten companies have webpages with information for the discard of electronics on the Brazilian websites. It has not been possible during the research to find any webpage informing about the disposal of products for the other two companies.

Graph 4 - Does the company has a webpage with information for the discard of electronics in Brazil?



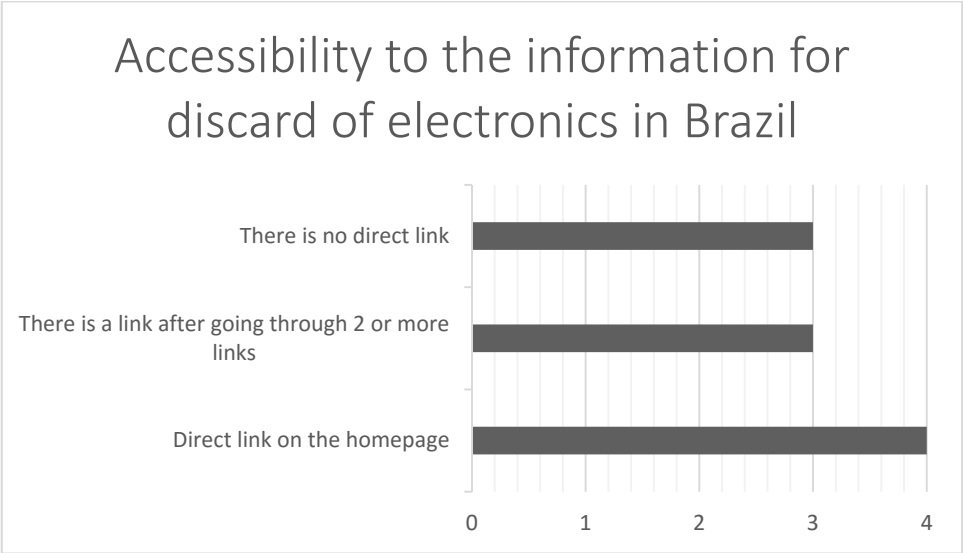
Source: Developed by the author

Still in relation to the webpages with information for the discard of electronics, another point analysed is the accessibility to this information on the companies' websites, as presented in *Graph 5*.

It is observed that only four out of the ten companies have a direct link for this information on the homepage of the Brazilian websites. For three companies, although the link for the information exists, it is necessary to go through at least two other links before obtaining it. The researcher could not find any direct link for the other three companies, for which two of them it has not been possible to find any information on the matter and the other one the link has been found only by using the searching tool.

Considering that raising awareness on the population about a proper disposal of electronics is a complex subject and involves a series of measures taken together, this also represents another hindrance in the process. As the process as a whole is not usually widely discussed, the information about it should be easily accessible, as a way to facilitate in every sense the propagation of such knowledge to the widest portion of the public possible.

Graph 5 - Accessibility to the information for discard of electronics in Brazil



Source: Developed by the author

Another point analysed is whether and, if positive, how the companies inform the public on their official websites in Brazil about how to proceed with the discard of their products at the end-of-life. Considering that, as discussed in chapter five - *Institutional and legal aspects for the management of electronic waste in Brazil*, the collection of the electronics produced is also the companies' responsibility, it aims at analysing how the main companies are dealing with this subject, which is still in period of adaptation.

As *Graph 6* demonstrates, 40% of the companies have announced on their webpages dealing with recycling of their products that the customer should contact the company either by sending an e-mail or by calling the customer service for further information on how to proceed with the discard. In this case, these four companies have specific e-mails for recycling issues given on their webpages. Besides, some of them ask already on their guidelines for the customer to provide information such as the product's model and serial number when contacting the company, in addition to the customer's city of residence for the company to be able to provide the best service.

From the ten companies analysed, two ask the customer to fill an online form available on their websites for the discard of the electronics. Both the companies make clear that the process is free of charge, demanding information on the form such as characteristics of the equipment and quantity to be recycled, besides the customer's personal data and address.

Graph 6 - Ways of discarding the product announced on the companies' websites in Brazil

Source: Developed by the author

Other two of the ten companies do not seem to directly conduct the process, but instead work in partnership with their technical assistance points. In this sense, they announce on their websites a series of collection points spread across the country to which the customer should take the product to be discarded.

Finally, as stated in *Graph 6,* the other 20% of the companies do not have a webpage on their official websites offering information about how to proceed with the discard of the electronics. After this analysis, it is easily observable that the companies have different approaches announced on their websites for the collection of electronics, in addiction to some of them not yet being fully prepared for dealing with the recycling of their products.

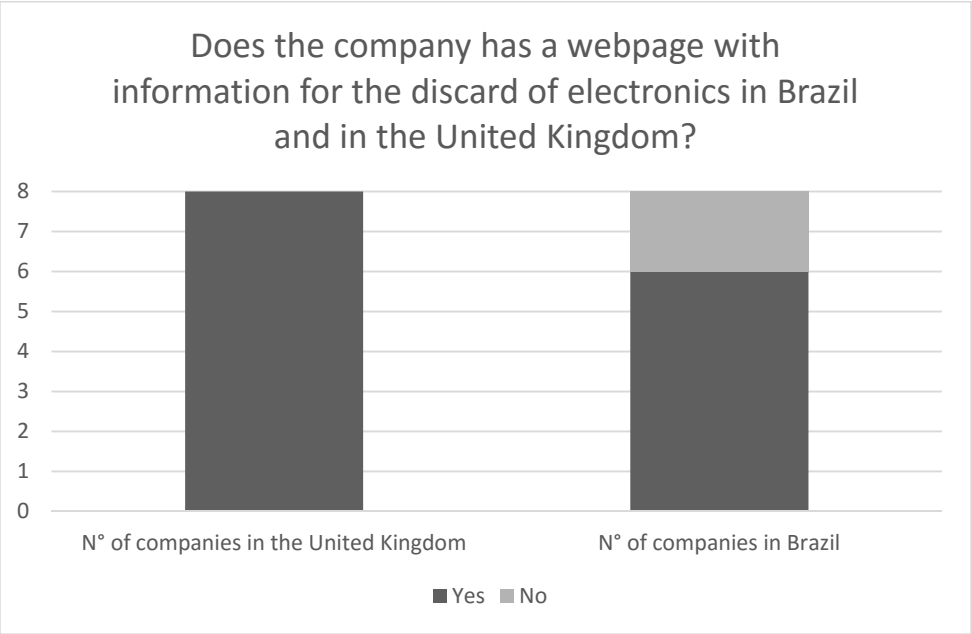
6.1.2 A comparison with the European websites: Brazil x United Kingdom

In line with one of the research objectives, which is *to analyse how some of the main electronics' manufacturers inform on their websites about actions towards recycling of electronics in Brazil and in Europe*, this part brings the comparison of information provided by the same eight companies in Brazil and in the United Kingdom.

Just as the Brazilian websites, all the companies analysed also have webpages with information dealing with social responsibility and sustainability issues in the United Kingdom, which shows commitment from the companies towards the subject in both scenarios.

Concerning the specific subject of electronics' collection for recycling, *Graph 7* brings the presence of a specific webpage with information for electronics' discard in the United Kingdom and in Brazil. While all the companies analysed in the UK have webpages with information for the discard of electronics, it has not been possible to find such webpage for two of the companies on the Brazilian websites.

Graph 7 - Does the company has a webpage with information for the discard of electronics in Brazil and in the UK?



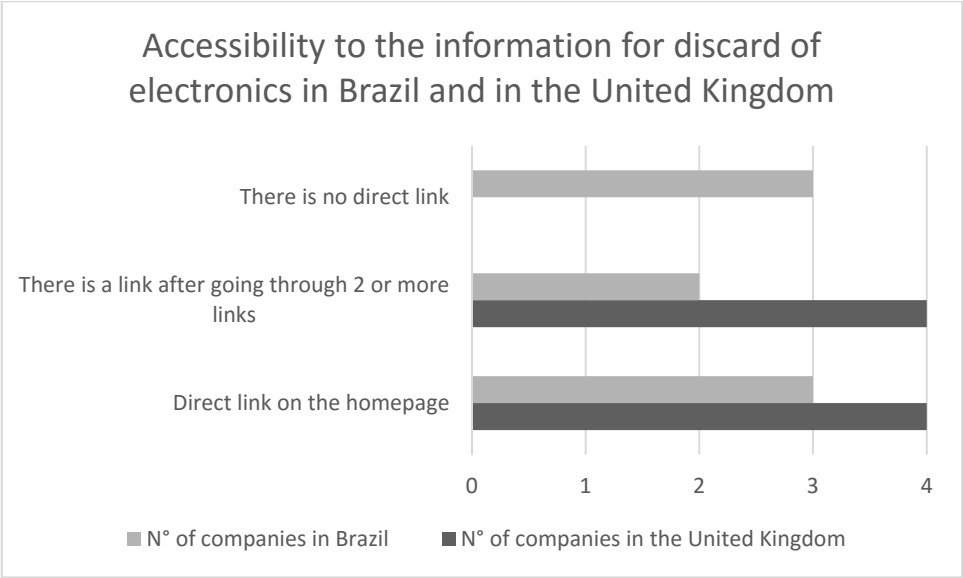
Source: Developed by the author

It is also analysed the accessibility to the information for discard of electronics on the websites of United Kingdom, comparing them to the Brazilian websites, which is demonstrated in *Graph 8*. All the eight companies have a link for the discard of electronics in the UK websites, while it has not been possible to find a link for three companies on the Brazilian websites.

Four companies analysed in the UK have a direct link on their homepages towards the discard of electronics. From these, three also have a direct link on their homepages on the Brazilian websites. For the other company, it has not been possible to find a direct link on the Brazilian version.

Still in relation to *Graph 8*, for the other half of the companies in the UK, it is necessary to go through two or more links until finding the page with information for discard. For two of these companies the same happens on the Brazilian websites, while for the other two the researcher has not been able to find a direct link or any information concerning the subject on the Brazilian websites.

Graph 8 - Accessibility to the information for discard of electronics in Brazil and in the UK



Source: Developed by the author

Other information analysed is whether and, in a positive case, how the companies inform the public about how to discard the electronics on their websites in the UK, compared to Brazil. From the analysis shown in *Graph 9*, only two companies have the same guidelines on the Brazilian and the UK websites, to which one advises to fill an online form for the recycling free of charge and the other asks the customer to deliver the product at a collection point.

Half of the companies analysed in the UK state on their websites that the individual customer should deliver the product at a collection point, while the commercial customer should contact the company by either filling an online form or sending an e-mail for the recycling free of charge. This option with distinction according to the customers is not stated by any of the companies analysed on the Brazilian websites. One of these companies in the UK also advises to contact the local municipality or to search on the Valpak consortium in the UK, in order to identify collection points. For the commercial customer, one company states on its UK website that the customer may profit from the residual value of the equipment. Other company in the UK states that the recycling free of charge is only for customers wanting to recycle more than

30 kg of equipment, otherwise the customer is asked to parcel and ship the equipment to a designated location by itself and on its own costs.

Graph 9 - Ways of discarding the product announced on the companies' websites in Brazil and in the UK

Source: Developed by the author

According to shown in *Graph 9*, two of the other companies in the UK ask the customer to fill an online form for the recycling free of charge. Some information demanded when filling the online form, besides the regular contact details, are the quantity, description of the product and the manufacturer/brand. One of the companies also asks for the device storage capacity, color, whether the device power up and function normally, if the device is free from signs of liquid contact, if the enclosure and the display are in good condition and if the buttons are working. For this company, the customer may get a gift card when returning an electronic. Both companies state on their websites to accept equipment from different brands. Two of the Brazilian websites also have the option of the online form.

The other two companies in the UK state that the customer should deliver the product at a collection point. One of the companies states that it works in partnership with REPIC, a WEEE producer compliance scheme in the country. The other company states that it is a member of the government sponsored Distributor Take Back Scheme (DTS) and, as such, it is not required to offer a take-back service for the electrical items it sells. Instead, the company states on its website to financially contribute to the DTS for assisting in the development of WEEE collection facilities throughout the UK. Only one of the companies analysed in Brazil asks on its website to deliver the electronic at a collection point.

Still in relation to *Graph 9*, three out of the eight companies analysed ask on their Brazilian websites for the customer to send an e-mail or call the customer service for further guidelines on how to discard the product. It has not been possible to find any information concerning discarding guidelines on the Brazilian websites of two companies. Both this options have not been found on the UK websites of the companies analysed.

6.2 Strategy of the "mysterious client"

The strategy of the *mysterious client* has been adopted as a way to analyse in practice how the ten major notebook manufacturers in Brazil are dealing with the collection of their electronic products at the end-of-life. More than that, it has aimed at identifying whether the companies are prepared for giving enough instructions for the customers about a proper disposal.

For this part, the researcher made contact by telephone with the customer service area from Brazil of all the ten companies between December 7th 2015 and December 9th 2015. By pretending to be a customer, the researcher informed to have a product of the company's brand, wishing to discard it and demanding the company's customer service about the best way to proceed with it. As the objective of this approach is to have a broad idea of the scenario, the companies are not individually identified.

As it is demonstrated in *Graph 10*, four of the ten companies contacted informed not to have any service offered for the proper discard of the electronic products, neither any collection point where it could be delivered. Among these companies, one of them advised to look for an independent place recycling electronic products, while other suggested searching for information with the city hall about how to make the proper disposal. One of the companies

specifically said that it was no longer responsible for the electronics' collection, since the warranty period of the product has passed.

Graph 10 - Customer service response in Brazil about the products' disposal

Source: Developed by the author

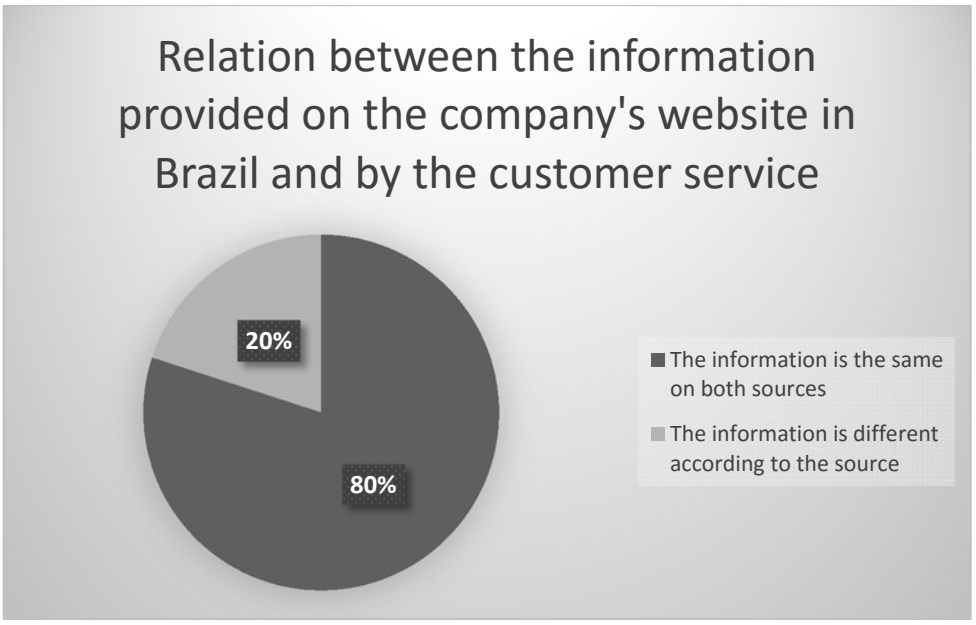
From the ten companies, two informed that the process works together with their technical assistance points and that the product could be delivered at any of them. For that, it was informed that on their websites there is the information and contact about the technical assistance points spread across the country. For one of these companies, a term of donation should be filled when delivering the product at one of the technical assistance points. It is interesting to highlight that, when contacting some of the technical assistance points that were announced on the companies' websites, they have all informed to accept electronic products of any brand.

The other four companies from the list informed to receive the product in a direct process. For one of these companies, the customer should send the product by mail service to the company's headquarters and pay for the mail service. The other three companies informed that the process of delivering the product is free of charge for the customer. One of them informed that the customer should send an e-mail to the company's specific recycling e-mail, to which a donation form would be issued together with the posting code for sending the product by mail service, without charge. For the other two companies, the customer should fill out an online form on the company's website and the company would then answer with the best option

for making the collection, the company either picking the product up at the customer's location or issuing a posting code for the customer to send it by mail. It is interesting to point out that, differently from the technical assistance points, these companies informed to receive only products from their own brand.

It is important to emphasize that the contact during the phone calls has only been made with the customer service area, not with any specific department for environmental issues or recycling. Therefore, the answers may, to some extent, not represent all the options provided by the companies for discarding the devices. Instead, it may evidence a lack of preparation from the companies to address the issue on the customer service area. Because of that, an analysis comparing the information provided on the companies' websites with the information provided by the customer service support is shown in *Graph 11*.

Graph 11- Relation between the information provided on the company's website and by the customer service



Source: Developed by the author

From this analysis it is possible to notice that, from the ten companies analysed, two have divergent information according to the source. Both have announced on their websites that the customer should send an e-mail or call the customer service with the information about the product (model and serial number) for the company to provide guidelines on how to send the product. However, the customer service of such companies have informed that there is no service or collection point offered from the company.

For the other eight companies, all information provided on their websites is the same of the one provided by the customer service. The two companies from the list that do not have any information on their websites concerning information for discard have also informed on the customer service that no service or collection point is offered. For the six remaining companies that have information about collection on their websites, either by technical assistance or directly, all the guidelines have been properly given by the customer service.

6.3 The interviews

The interviews have been conducted with the Brazilian Association for Electronics and Home Appliances Recycling (ABREE), two companies from the list and one recycling partner of another company from the list of the ten major notebook manufacturers in Brazil. As the main objective of the interviews is to study the broad companies' scenario, the companies are not individually identified.

Due to territorial and financial constraints, all the contact for the interviews has been made by telephone and e-mails. The questions' guides used to make contact with ABREE and with the companies are presented on the appendices. *Appendix A* presents the introduction letter used for all the interviews in its original version, while *Appendix B* is the translated version. The questions used for ABREE are presented in *Appendix C* in Portuguese and in *Appendix D* in English. The questionnaire used for the manufacturing and the recycling companies is presented in *Appendix E* in its original version and in *Appendix F* in the translated one.

6.3.1 ABREE

The Brazilian Association for Electronics and Home Appliances Recycling (ABREE) is a non-profit organization founded in 2011. According to information provided on its official website, ABREE manages the electronic waste of its associates, being responsible for carrying out any reverse logistics activity and a proper environmental destination. It also represents its members in related activities, such as audits and defense of interests. The interview has been conducted with the executive manager of the association.

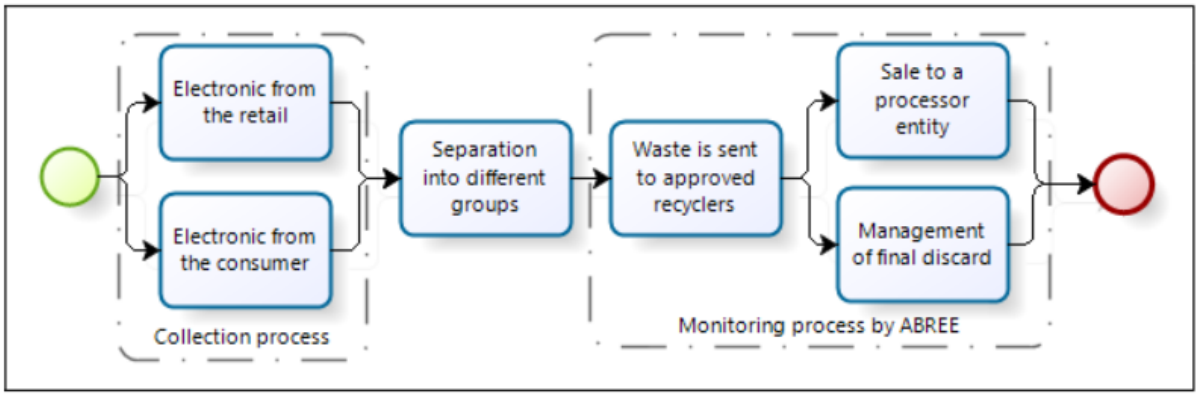
The association has three partners announced on its official website, which are Eletros, Eletrolar and ERP. According to the information provided on the interview, Eletros, just as ABINEE, defends the sector as employers' associations. Eletrolar is ABREE's institutional

partner and the European Recycling Platform (ERP) is the association's consultant in the technical area.

Having as one of its main principles to promote the reduction of costs to its members by providing collective negotiations and an economy of scale, ABREE states that it outsources all of its activities, such as transportation, storage, recycling and technical operational workforce. Just as the *National Solid Waste Policy* is applied to the whole country, the association also works on a national basis.

Figure 14 brings the basic idea of process for the recycling of electronic products managed by ABREE. The diagram is based on the answers provided by the association and has been constructed by the author.

Figure 14 - Process of electronics' recycling for ABREE



Source: Developed by the author

For the process itself, the association claims to work with two different ways of collection, either by receiving the electronics from the retailing or from the consumer. On the consolidation part, ABREE states that it separates the waste into different groups to be sent to specific recyclers. For the recyclers to work with ABREE, they first should be approved by the association, just as their environment and working safety. After that, the association says it monitors the waste delivered to the recyclers until the correct disposal takes place, either by selling it to a processor entity or by managing the final discard. Either way, these processes are evidenced with fiscal documents, according to the interview. Besides, it has been informed that, although ABREE does not do the specific process or interfere on it, the printed circuit boards, with economic value, are exported.

Concerning the PNRS, the association has specified mainly two points in which the policy could be improved. One point is the education and the definition of rules that should be

made in a clearer manner than currently. According to ABREE, the PNRS seems too generalist, as it addresses all sorts of waste in a general manner, while clearly each sort of waste has particular characteristics. Another point addressed is the need for the policy to be taken with a collective approach, which is a matter of environment, public health, space and especially a shift of paradigms.

When talking about the main adversities and uncertainties in the electronic recycling process in Brazil, ABREE has highlighted the lack of recyclers as the main bottleneck. The lack of studies about WEEE and its quantities, besides the lack of environmental consciousness for a correct disposal of the products have also been pointed out. The association has affirmed to be currently preparing a strategic plan to deal with the communication for the public and environmental education regarding the electronic waste.

According to the association, most of the electronic companies in Brazil are not aware of the requirements and procedures for the reverse logistics and correct environmental disposal of the electronic waste. It has also pointed out that, by visiting operations abroad, it is easily possible to notice how much Brazil has to improve its processes, besides the good opportunities for raising employment and income that lies in this sector.

As ABREE represents an association of companies that have put efforts together to solve a problem in common, the association defends that this is the best solution for the electronic waste sector. It also believes that the complete process of electronics' recycling can be a profitable business in the country, as much more than the value of the residues, there is the value of the service delivery by acting on the chain.

6.3.2 Company A

Company A aims at being the leader in sustainability and green IT solutions in the country by creating differentiation, competitiveness and preference of its products, according to the interview. At the same time, it claims to contribute to its customers' environmental awareness on the use of its products. Because of that, the company has been recognized for the leadership in sustainability and has received numerous awards, specified on its website. Among these awards, there is the *Eco Brasil 2015* in the category of processes with the case of circular economy, besides elected as one of the most sustainable companies in the electronics sector in Brazil by the sustainability guide Exame in 2013 and 2014.

Concerning sustainability practices, company A affirms that the global citizenship vision is connected with the company's objectives since its foundation. According to the

interview, both the company and its suppliers respect the code of conduct of the *Electronic Industry Citizenship Coalition* (EICC) on a global scale. Among the company's policies, there is the environmental, the health and the safety policy.

Company A has a programme entitled *Planet Partners*, in which it deals with the recycling of its products after the end-of-life. This programme operates in Brazil in partnership with the company *Sinctronics*. As the sustainability brand of *Flextronics International Technology*, the company has informed that *Sinctronics* conducts all the programmes of reverse logistics management for the products at the end of life for company A in Brazil. By managing the operation directly with *Sinctronics*, company A defends to be able of properly serving its customers, without being connected to any class institution.

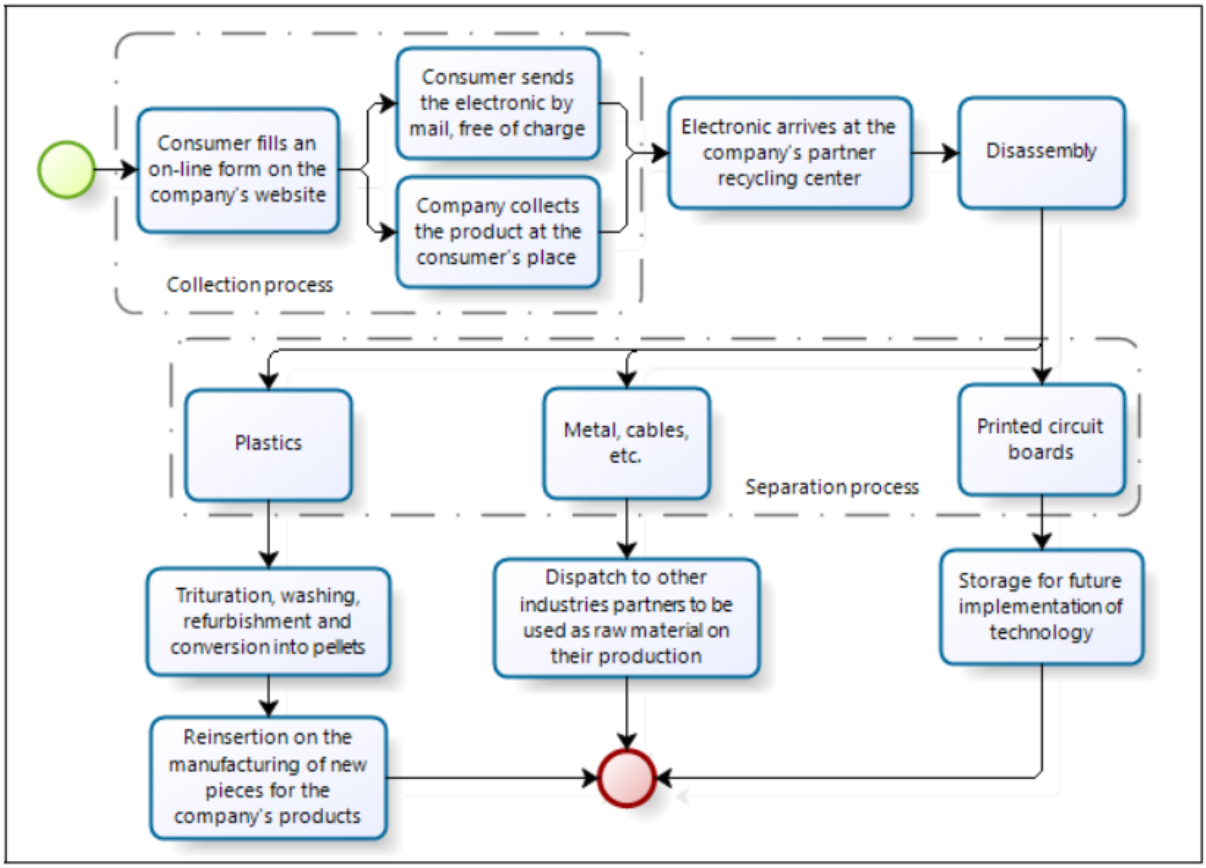
According to the information provided on *Sinctronics*' official website, this company was created in 2012 as a center for innovation and sustainable technology, representing the first integrated ecosystem for sustainable solutions towards the market of electronics in Brazil. Further, it states to apply the concept of circular economy in its processes, just as discussed in the literature review. With the goal of raising the concept of waste recycling to an industrial scale and integrate it to the manufacturing chain, the company claims to collect and turn the electronic waste into raw materials or pieces for new products. Furthermore, it is stated on *Sinctronics*' website that it represents a reference center by including reverse logistics, processing of materials, social inclusion, environmental education and investment on research and development.

According to the interview, *Sinctronics* manages the whole process for company A, from the customer collection wishing to dispose of its product to the reinsertion of the materials as new pieces in the economy, closing the circular economy loop. Company A states that the products at the end-of-life are collected by transporters' companies duly recognized by *Sinctronics*. After that, they are taken to the *Sinctronics Recycling Center* in the city of Sorocaba - SP, where the recycling process and the production of new pieces takes place.

Company A states that the process of collection starts when the consumer opens a call on the internet by filling an online form. After that, the company's partner receives the request and directs the consumer to the best way of collection, depending on the amount and volume of products do be returned. The collection may happen either with the transporter's company picking the product up at the consumer's place or the consumer sending the product by mail. Independently if the consumer is an individual or company of any size, the company affirms that the collection is free of charge for the customer.

Figure 15 shows the process for the recycling of the electronic devices produced by company A, since the collection from the customer to the final disposal. The diagram is based on the answers provided by the company and has been built by the author.

Figure 15 - Process of electronics' recycling for company A



Source: Developed by the author

Concerning the separation of parts, the company specifies that the sorting is made according to the components when arriving at the *Recycling Center of Sinctronics*. All parts are separated by type, from plastic to metal and cables. According to the information given, the plastic parts are triturated, washed, refurbished and converted into pellets to be reinserted on the manufacturing of new pieces for company A's products. Further, the components that are not reinserted on its manufacturing process are sent to other industries partners for them to use the raw material on their value chains. It has been highlighted that no component collected by the *Planet Partners Program* is sent to landfills.

When asked about exportation of components for recycling, company A answered that all the components are recycled in the country. Nevertheless, there are some components, like

the circuit boards, for which the company states that there is not yet a proper technology for recycling. The company specifies that its partner has a center for R&D, in which is working on the technology development for this case and that these specific materials are currently being stored until such technology is complete and implemented.

Concerning strategic approaches, company A has been asked whether they would consider performing the activities of recycling, which are currently outsourced, by their own in the future. The company has answered that they do not consider performing such activities, as they are not the core of the company.

It has also been highlighted about the high costs of recycling the electronic devices. Mainly due to the reverse logistics still very expensive and not well developed in Brazil, the experience of company A has shown that the costs are still very significant, not being a profitable business in the country. The company believes that by working together with other manufacturers, distributors, importers and retailers it would be possible to reduce such costs, but only when the *National Solid Waste Policy* is regulated.

The company has pointed out the lack of regulations of the PNRS as one of the main adversities and uncertainties in the process of electronic recycling in Brazil. The company argues that, taking 20 years to be approved, the policy unfortunately has several gaps, such as the tax law, collection points, random targets and the shared responsibility. Such points, according to the company, should be addressed in a better manner than currently.

Regarding communication tools and initiatives for informing the public about a proper disposal of the electronic products at the end of life, company A defends that there are several in practice. The company has a specific website in Brazil for recycling of their products. In addition, it claims to make regular campaigns on its social media and forums for the public, while always warning the corporate customers about the best ways of disposing their products. The communication should also happen in the distribution of new products. According to the interview, the new products when delivered include a booklet in addition to the operating manual, in which there is specific information for the sustainable disposal of the equipment at the end-of-life through the collection and recycling programme.

6.3.3 Company B – Recycling partner

Company B operates for the recycling process of its electronic products in partnership with a company that, according to its website, is specialized and one of the pioneers in the

country in environmental solutions for the disposal of electronic products, which started its operations in 1998. In this case, the interview has been conducted with the supervisor of operations of this recycling company.

The company says it has recycling partnerships and contracts with several electronics manufacturers, to which company B is one of them. In some cases, it hires transportation and in other cases the manufacturing company delivers the product. First of all, the loads are scheduled and they are only received with a fiscal receipt or a declaration of waste transport, according to the interview. When arriving at the recycling center, the material may either be stored or dismantled immediately, depending on the contract. After the dismantling process, the recycling company states that all the by-products are separated to be sold to homologated companies. The operating process being complete, the company affirms to issue a certificate of final destination.

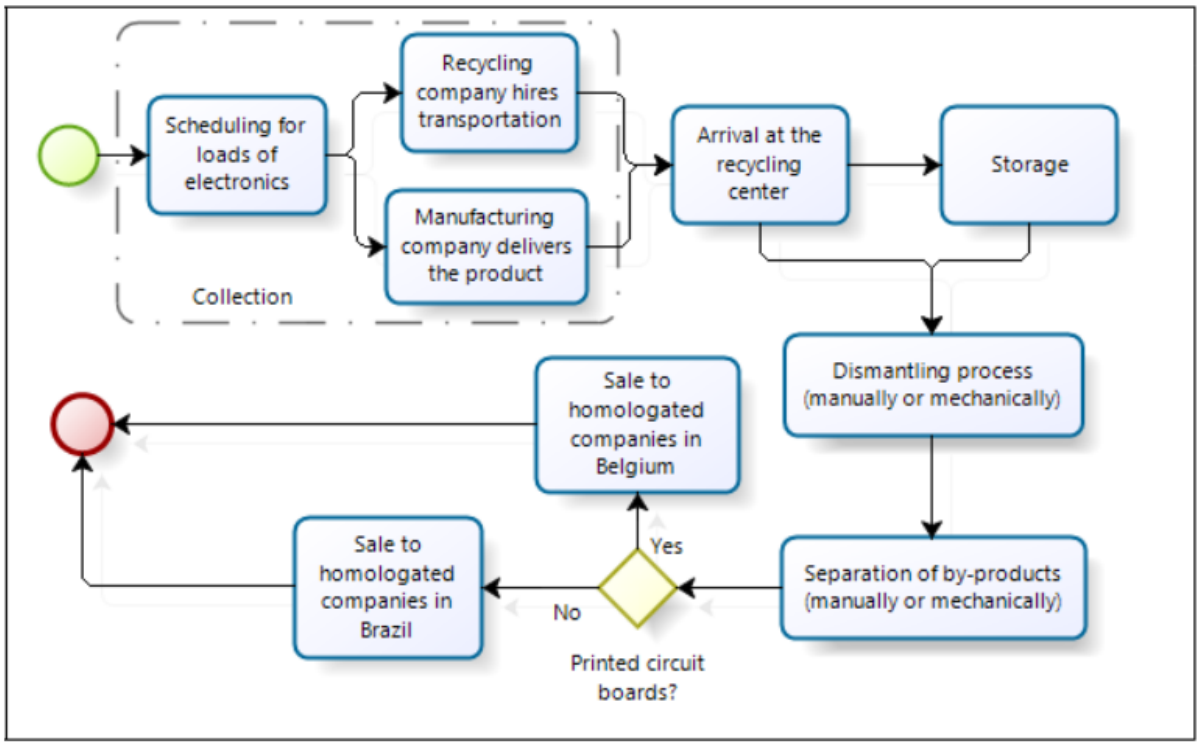
The company states that it performs all the activities involving operations for recycling with its own employees, not outsourcing activities. About communication tools, the company says to inform about the proper disposal for its partners with which it runs the recycling programmes, to which company B is one of them.

For the collection of the electronic waste, according to the information provided, the client should first inform the amount of material for the best way of managing transportation, in addition to how the material is being stored. After making the quote with the transportation companies that are already homologated and having the client's approval, the material is then collected and delivered at the recycling center.

In relation to the process of dismantling and separation of pieces, the recycling company states that all these processes are made either manually or mechanically. For that, the company makes use of pneumatic screwdrivers, tools like plier, screwdriver and hammer, in addition to a plasma cutting machine and two crushers. The by-products are then separated according to their classification and, when having a sufficient amount of material, the company negotiates with the recycling companies and sells them. The company states that there are pieces not yet recycled in Brazil, which is the case of the printed circuit boards that are sent to Belgium for recycling.

Figure 16 demonstrates the recycling process of the electronic products produced by company B, which are recycled by its recycling partner. Based on the answers provided by the recycling company, the diagram has been built by the author.

Figure 16 - Process of electronics' recycling for the recycling partner of company B



Source: Developed by the author

The recycling company believes that the complete process of recycling of electronic waste may be a profitable business in Brazil. It has been mentioned that the process of reverse manufacturing is not a highly complex process in the sense of not requiring the latest equipment with high value.

Concerning suggestions for improvement of the *National Solid Waste Policy*, the recycling company points out to the lack of residues' classification. It specifies that the PNRS is not very clear about many issues concerning electronic waste, although this waste has a very different classification and suffers from constants technological changes. The company has also mentioned this classification of residues as one of the main uncertainties and adversities in the process of electronics' recycling in Brazil.

6.3.4 Company C

Company C promotes initiatives towards sustainability issues announced on its website. In order to inform the public about a proper disposal of electronic products, the company affirms

to provide the necessary information especially on the packaging and manuals, in addition to a specific webpage for the recycling of its products.

According to the interview, the company makes the collection of its products for the recycling with the help of its network of technical assistance shops spread across the country. The dismantling and recycling processes are centered in Curitiba - PR and, as stated by the company, comply with all the local, state and federal legal requirements. In the context of the shared responsibility, the company affirms to takes measures for ensuring the implementation and operation of the reverse logistics system of its products at the end-of-life. Company C does not accept for recycling electronics produced by other companies.

In accordance with the information given, the collection process starts with the product's arrival at the technical assistance, then heading to its waste plants for the process of dismantling and dispatch to the recycling companies. From the waste plants, the residues are sent to specialized and licensed companies for the treatment, management and transport to the final destination. The company highlights that all this process includes constant reviews and auditing of the recyclers, besides all the mitigation and preventive measures working according to the norms of ISO 14001 from 2004.

Company C says its central unit for the electronic waste works as a separate unit. It is responsible for the sorting of not only the products at the end-of-life from the retail, corporate and government; but also for the obsolete products, the scraps, materials internally discarded and separated pieces from the technical assistances.

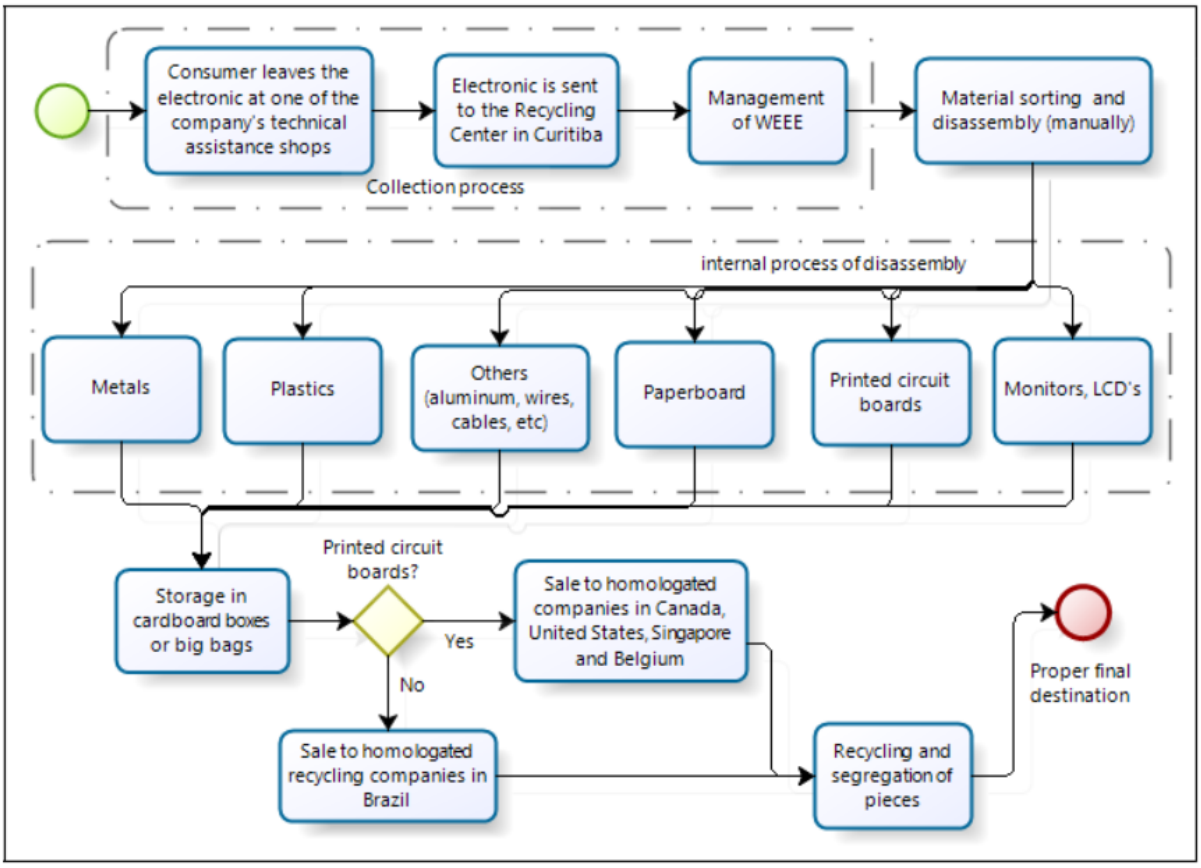
Concerning the separation of pieces, the company states that the components are manually separated and, after that, placed in cardboard boxes or big bags for further delivery to a recycling company or other environmentally friendly destination. As previously discussed, company C has also mentioned that Brazil does not yet have the necessary technology for recycling certain components and, because of that, many companies carry out the collection, shredding and reverse manufacturing process to then send some components to specialized companies abroad. This is the case also for company C, which sends some components to countries like Canada, United States, Singapore and Belgium. For the other components such as glass, plastic, metal and cardboards, the company states that the process is done on national ground.

For the management of its electronic waste, company C argues that it moves efforts to ensure that the waste is recycled by licensed and authorized institutions, which use enough technology to promote the maximum recovery of materials before the final disposal. In order to monitor such activities, the company says it promotes studies and action plans towards

specific actions, which have been so far presented to the *Electronic Product Environmental Assessment Tool* (EPEAT). In addition, it claims to have other actions with the diverse actors of this supply chain, including distributors, associations, recyclers, consumers and the public sector.

Figure 17 demonstrates the idea of process for the recycling of the electronic products produced by company C. The diagram has been built by the author, based on a previous one provided by the company, in addition to the answers given on the interviews.

Figure 17 - Process of electronics' recycling for company C



Source: Developed by the author

The company affirms it does not consider performing on its own the activities of recycling that are currently outsourced. The reasons for that seem to be many, such as the ones mentioned of the wide range of product's models that makes a considerable variation on the composition of each scrap, the many existing laws and legislations and the large number of manufacturers. In addition, it has been highlighted that it is not part of the company's core and that there are a series of difficulties about the logistics, especially because of the large dimensions of the Brazilian territory.

Still in relation to the outsourcing of the recycling activities, the company has highlighted some of the many points that would come as consequences of performing the activities on its own. Among them, the company would have to manage the collection programmes, require and maintain recycling certificates, track down the materials along the chain, conduct auditing activities in the recycling companies and create collection and sorting points; which would mean to create another business. Besides, the company has pointed out that, due to the high investment in equipment required for the activity, it would be necessary large amounts of electronic waste in order to make the business a profitable one.

Company C does not believe that the complete process of electronic waste recycling may be a profitable business in Brazil. Among the main adversities and uncertainties in the process, it has been mentioned the cost model and the fiscal policy. The company argues that there is the need for investments in the sorting and in the reverse logistics process for this sort of waste. The development of integrated waste management and solid waste management plans have also been addressed, among with the development of environmental management systems aimed at the improvement of production processes and recycling of waste.

Regarding the *National Solid Waste Policy*, the company has mentioned the sectoral agreements as a possible solution to a series of hindrances in the law. Among the many hindrances, the company says there is the lack of a simplified tax policy for the handling of the electronic waste, the uncertainty about the necessity of licensing incoming centers and homologating the container and the lack of recycling companies technically and legally appropriate.

According company C, there is also a lack of a common ground in the PNRS for the management, handling and storage of products at the end-of-life; the difficulty of transport for some regions of the country; the creation of divergent laws by Municipalities and States; and the complexity of some products due to size, packaging and technology. Finally, the difficulty of disposing the waste in an environmentally friendly way in certain regions of the country and the lack of a Federal law for the definition of financial statement for the provision of resources to cover the returning process have also been mentioned.

6.4 Discussion about the companies' strategies towards the recycling of electronics

On the first part of the website analysis, the websites of all the ten major notebook manufacturers in Brazil have been analysed. Concerning the language towards social

responsibility/sustainability issues, only two have all the information in Portuguese, while half of them have the information mixed in Portuguese and English on their websites and the other three have all the information given in English. Such data could indicate just that these companies are not yet prepared to deal with the issue in Brazil or that informing the public about such matter is not view as strategic from the companies' perspective. In regard to the information about discarding the electronics, eight of the ten companies have a webpage with information for the electronics' discard in the country. Nevertheless, only four of them have a direct link for this recycling page on their official homepages, being easily accessible for the Brazilian public.

It is possible to connect the information on the companies' webpages about the language and the discard of electronics with the section of *Strategy for the reverse logistics and recycling of electronics*. If analysed from a strategic point of view, it is possible to conclude that for many companies in Brazil the subjects of sustainability and recycling of electronics are not being seen from a strategic point of view. If the companies saw such subjects as a strategy of differentiation in the market, just as discussed in the literature review, it would be expected different results from the website analysis.

More specifically, if it was part of the companies' strategy, it would be interesting for them to inform the public in Portuguese about their approaches, in order to embrace the largest portion of customers possible in Brazil. In addition, if it was part of their strategy of differentiation, it is assumed that the companies would also inform about the discard of electronics in the easiest possible way, with a direct link on their homepage, instead of having to go through many links until finding any information about it. Therefore, what has been observed is that most companies are dealing with the matter in terms of obligation in Brazil, in order to obey laws and regulations.

The companies have different ways of discarding the electronics announced on their websites. While two of them recommend the customer to deliver the electronics in any of the technical assistance points announced on their website, other two ask the customer to fill an on-line form for the recycling free of charge. Four of the ten companies inform the customer to send an e-mail or call the customer service for further guidelines, while the other two have no information about how to make the electronics' disposal.

By making contact with the customer service support of the major notebook manufacturers in Brazil and pretending to be a customer trying to discard its electronic product, it has been possible to have a broad idea of how the companies are prepared to inform the public about their actions towards recycling. From the ten companies contacted, four have informed

not to have any service or collection point provided for the discard of their products. Other two have stated that the product should be delivered at any of their technical assistance points spread across the country, which are informed on the companies' websites. The other four companies have answered that they receive the product directly, either the customer sending it by mail service or the company picking the product up at the customer's place. Only two of these companies have online forms on their websites to be filled for the collection and only three of the companies announced on the customer service support to offer the service free of charge for the consumer.

After the website and the customer support analysis, it has been possible to make a comparison of the information provided between the two sources. Of the ten companies, two have provided different information on the customer service support from the information provided on the company's website, which could indicate a lack of companies' preparation to deal with such issue. It has been possible to observe that, while some of the companies have shown to be seriously engaged with actions towards collection of their products and with employees' preparation to inform the customers about a proper disposal, other companies have made clear that they are not yet prepared to address such an important issue, providing divergent information.

The second part of the website analysis involves the eight companies from the list that are present worldwide, by comparing the information towards recycling given on their websites in the United Kingdom with the information given in Brazil. *Table 4* brings a comparison for the companies analysed in both scenarios.

Just as the Brazilian websites, all the companies in the UK have webpages dealing with sustainability issues. Concerning information for discard of electronics, all the companies in the UK have a specific webpage towards the matter, while in Brazil two of the companies do not. In regard to the accessibility of information, while all companies in the UK have a link for the discard on their websites, it has not been possible to find a link for three of the companies in Brazil.

Table 4 - Comparison between companies in Brazil and in the United Kingdom

Company	How is it possible to obtain information for discard in the UK?	How is it possible to obtain information for discard in BR?	How to discard its product in the UK (information on the websites)	How to discard its product in BR (information on the websites)
1	Direct link on the homepage.	Direct link on the homepage.	Deliver the product at a collection point.	Deliver the product at a collection point.
2	Direct link on the homepage.	Direct link on the homepage.	Fill an online form for the recycling free of charge.	Fill an online form for the recycling free of charge.
3	Direct link on the homepage.	Direct link on the homepage.	The individual customer should deliver the product at a collection point. The commercial customer should fill an online form/send an e-mail for the recycling free of charge.	Fill an online form for the recycling free of charge.
4	Direct link on the homepage.	There is no direct link.	Fill an online form for the recycling free of charge.	Send e-mail or call the customer service for the company to provide guidelines on how to discard the product.
5	There is a link after going through 2 or more links.	There is a link after going through 2 or more links.	The individual customer should deliver the product at a collection point. The commercial customer should fill an online form/send an e-mail for the recycling free of charge.	Send e-mail or call the customer service for the company to provide guidelines on how to discard the product.
6	There is a link after going through 2 or more links.	There is a link after going through 2 or more links.	The individual customer should deliver the product at a collection point. The commercial customer should fill an online form/send an e-mail for the recycling free of charge.	Send e-mail or call the customer service for the company to provide guidelines on how to discard the product.
7	There is a link after going through 2 or more links.	There is no direct link (No information).	The individual customer should deliver the product at a collection point. The commercial customer should fill an online form/send an e-mail for the recycling free of charge.	No information.
8	There is a link after going through 2 or more links.	There is no direct link (No information).	Deliver the product at a collection point.	No information.

Source: Developed by the author

When it comes to the ways of discarding the product, most of the companies have different approaches depending on the country. While with different actions according to the company, all companies in the UK have direct guidelines to what should be done. On the other hand, two of the companies in Brazil have no information at all about a proper disposal, while for other three the information is rather insufficient, as it asks the customer to send an e-mail to the company or call the customer service.

Therefore, when analysing the whole scenario, it has been possible to observe that, even for the same companies, there are many differences in the way the processes are being conducted in both countries. It important to highlight the different realities of both countries in terms of resources, technology, infrastructure and laws. Nevertheless, it is evident from the analysis that the companies in the UK are adopting more approaches towards informing the public about a proper discard of electronics than the same companies are in Brazil.

It is possible to notice from *Table 4* that only two of the eight companies analysed have the same guidelines for discarding the products in both countries. The other six companies have divergent approaches both in terms of accessibility to the information for discard of electronics and ways of discarding the product. Therefore, it is possible to assume that, for the majority of the companies analysed, the strategy taken differs according to the scenario.

Taking into consideration the likely assumption already mentioned when analysed the ten companies in Brazil, the results have shown that most companies in Brazil are not looking at the recycling process as beneficial to their business. Therefore, instead of making part of the company's strategy of differentiation, the actions towards recycling are being put into practice mainly due to legal requirements.

As such, a possible explanation for the companies to have different approaches according to the countries could be because of the different laws and regulations in practice on both countries. As already described in chapter four - *The European scenario*, the European legislation towards electronic waste has series of measures into practice, which could be demanding the UK companies to have more rigorous operations than the same companies in Brazil.

Another part of the chapter consists on the interviews conducted with ABREE, two of the ten companies from the list and one recycling partner of another company from the list, to which a series of points have been analysed. For the recycling process itself, it has been possible to identify that the companies are dealing with the matter in different ways, both in terms of collection and for the recycling process itself. Either way, they all have demonstrated to work

together with recycling partners to complete de process. For the dismantling part, the process is done mechanically or/and manually and for the specific case of the printed circuit boards, all the companies have answered that there is not enough technology in the country to recycle them, reason why most of the companies export them for recycling.

Table 5 - Comparison among the interviews

	ABREE	Company A	Company B's recycling partner	Company C
Are there pieces not recycled in Brazil? If so, which ones and what is their destination?	Yes. Although the company does not interfere on the process, the printed circuit boards are exported.	All components are recycled in the country or stored. Currently working on the technology development for recycling some components.	Yes. The printed circuit boards are sent to Belgium for recycling.	Yes. Some components are sent to countries like Canada, United States, Singapore and Belgium.
Does it believe that the process of e-waste recycling can be a profitable business in Brazil?	Yes	No	Yes	No
Suggestions for improving the PNRS	The education and the definition of rules should be made in a clear manner. It needs to be taken with a collective approach, involving a shift of paradigms.	It has several gaps, such as the tax law, collection points, random targets and the shared responsibility.	It is not very clear about many issues concerning electronic waste.	Sectoral agreements as a possible solution to a series of hindrances in the law.
Main adversities and uncertainties in the recycling process of electronics in Brazil	Lack of recyclers, environmental consciousness and studies about WEEE and its quantities.	Lack of regulations of the PNRS.	Lack of residues' classification on the PNRS.	The cost model and the fiscal policy.

Source: Developed by the author

Table 5 shows some points highlighted on the interviews concerning specially strategic and regulatory matters. Concerning the PNRS, a series of critics and suggestions have been mentioned to improve the current policy. Most of them have appointed the law not specific to the electronic waste as a problem, since this particular waste has its own characteristics. The policy should, then, improve the definition of rules and the classification of residues. Several other gaps have been mentioned, like the collection points, random targets and the tax law. In addition, while the collective approach is needed for the process, the shared responsibility appears in a too generalist way on the policy.

Directly related to the section of *Innovation and uncertainties in the recycling of electronics* from the literature review, the companies have named what they consider to be the main adversities and uncertainties in the recycling process of electronics in Brazil. The lack of regulations and classifications of residues on the PNRS have been emphasized. The fiscal policy, the cost model and the high investments needed in the sorting and in the reverse logistics have also been mentioned. Besides, the lack of studies about WEEE and its quantities, the need for more recyclers and the lack of environmental consciousness have also been addressed as bottlenecks in the process.

When dealing with the profitability issue of the recycling of electronics, the opinions have been divergent. Both the association and the recycling company believe that the complete process of electronics' recycling may be a profitable business in Brazil. While ABREE has mentioned that there is value on the residues and also on the service delivery by acting on the chain, the recycling partner for one of the manufacturing companies has said that the recycling does not require the latest equipment and it is not, then, a highly complex process. On the other hand, both manufacturing companies do not consider performing on their own the recycling activities that are currently outsourced, neither they believe the recycling process of electronics to be a profitable business in the country. The manufacturing companies have pointed out that such activities are not the core of the company and that the costs are still very significant, especially in terms of the reverse logistics not well developed and the complications with the country's extension.

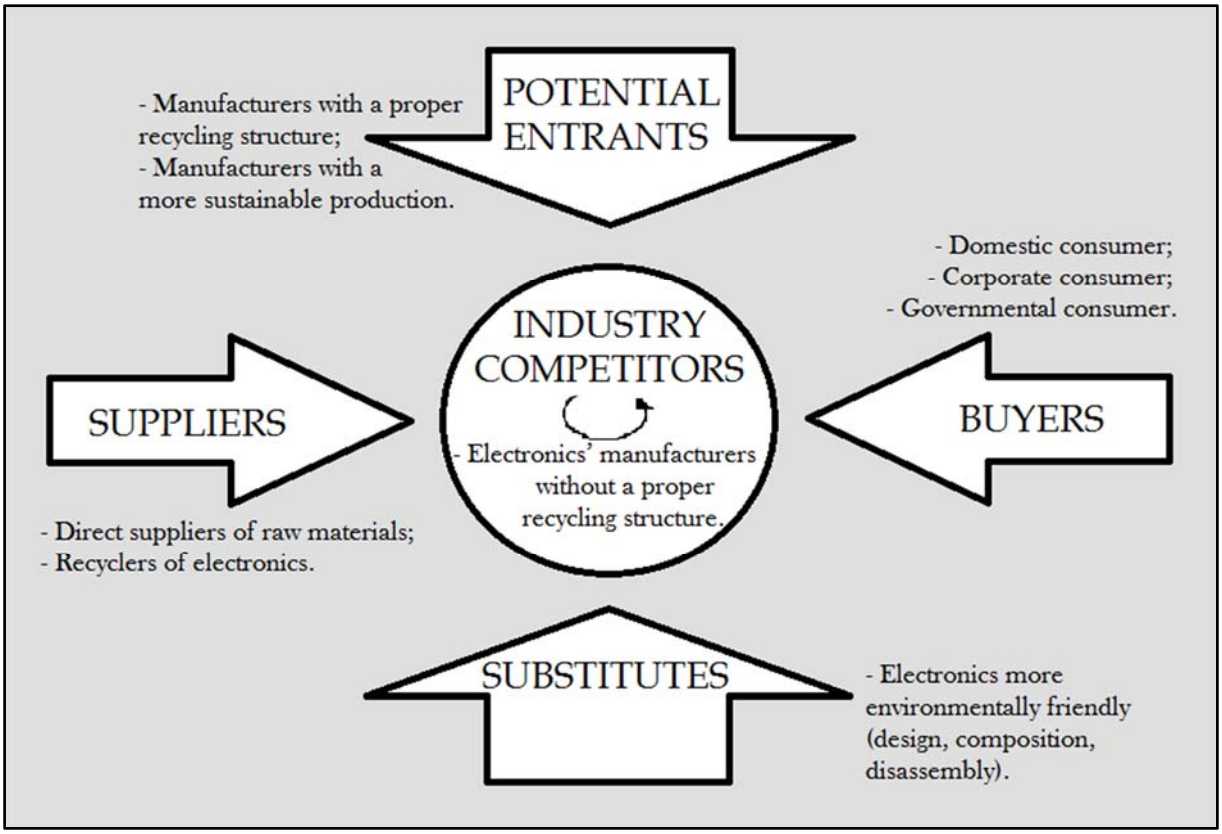
About communication tools for the proper discard, both manufacturing companies have specific information towards the correct discard announced on their websites. In addition, they inform the new customers on how to proceed with the sustainable disposal of the equipment at the end-of-life by giving information on the new products that are acquired, either on the packaging or the manuals.

6.4.1 Companies' strategies towards the recycling of electronics analysed from the perspective of Porter

In the section *Strategy for the reverse logistics and recycling of electronics,* some strategic models from the scholar Michael Porter have been highlighted. Based on such models presented on the literature review and on the results from the current research, this section discusses the five forces model and the diamond model applied to the recycling of electronics. The five forces model is analysed from the local behavior of the manufacturing companies in Brazil, while the diamond model is looked from an international perspective of companies in the different scenarios, with focus on the case studies analysed for Brazil and the United Kingdom.

In the five forces model, Porter specifies the forces influencing the industries' competition, which are the threat of potential entrants; the bargaining power of suppliers; the bargaining power of buyers; the threat of substitute products or services; and the competition among existing industries.

Figure 18 - Porter's five forces applied to the recycling of electronics



Source: Developed by the author

Figure 18 brings the five forces model applied to the recycling of electronics, highlighting some aspects identified during the case studies with some of the manufacturing of electronics present in Brazil. It does not represent any specific company, but rather a general view of the scenario.

One of the forces from the model is the competition among existing industries. In this case, the current scenario of electronics' manufacturers in Brazil is that they do not have a proper recycling structure. More specifically, there seems to have a big gap between manufacturers moving efforts to recycle their products by establishing partnerships with recyclers from manufacturers that are clearly not focusing on this particular issue. In either case, the broad scenario in Brazil shows that even the companies that are seriously engaged with more sustainability actions are not performing the whole recycling activities by themselves.

Other force from the model is the threat of potential entrants. By linking with the already existing industries, it is logical to think of a possibility for new entrants as electronics' manufacturers with a proper recycling structure as part of their business strategy. Another possibility of new entrant could be electronics' manufacturers with a more sustainable production. Both these possibilities could, if proper designed and implemented, make the product cheaper, which could represent a threat to the existing firms.

The bargaining power of suppliers is another force highlighted in the model. In the production of electronics, although there are evidently the direct suppliers of raw materials, another actor could also play an important role in the supply sphere. If a proper recycling process was into place, the recyclers of electronics could also be an important source of material. This, if taken from the company itself, could decrease the production costs of new electronics, in addition to being more environmentally friendly with a circular model of production.

The bargaining power of buyers is also one of the five forces presented. In this sense, it is interesting to consider that the industries have diverse sectors of consumers. In addition to the domestic consumer, the electronics produced may also be for the corporate and the governmental consumers. As such, the demand of more sustainable products and ways of proper discarding the electronics may come from different sources, pressuring the existing firms to adapt to the new reality.

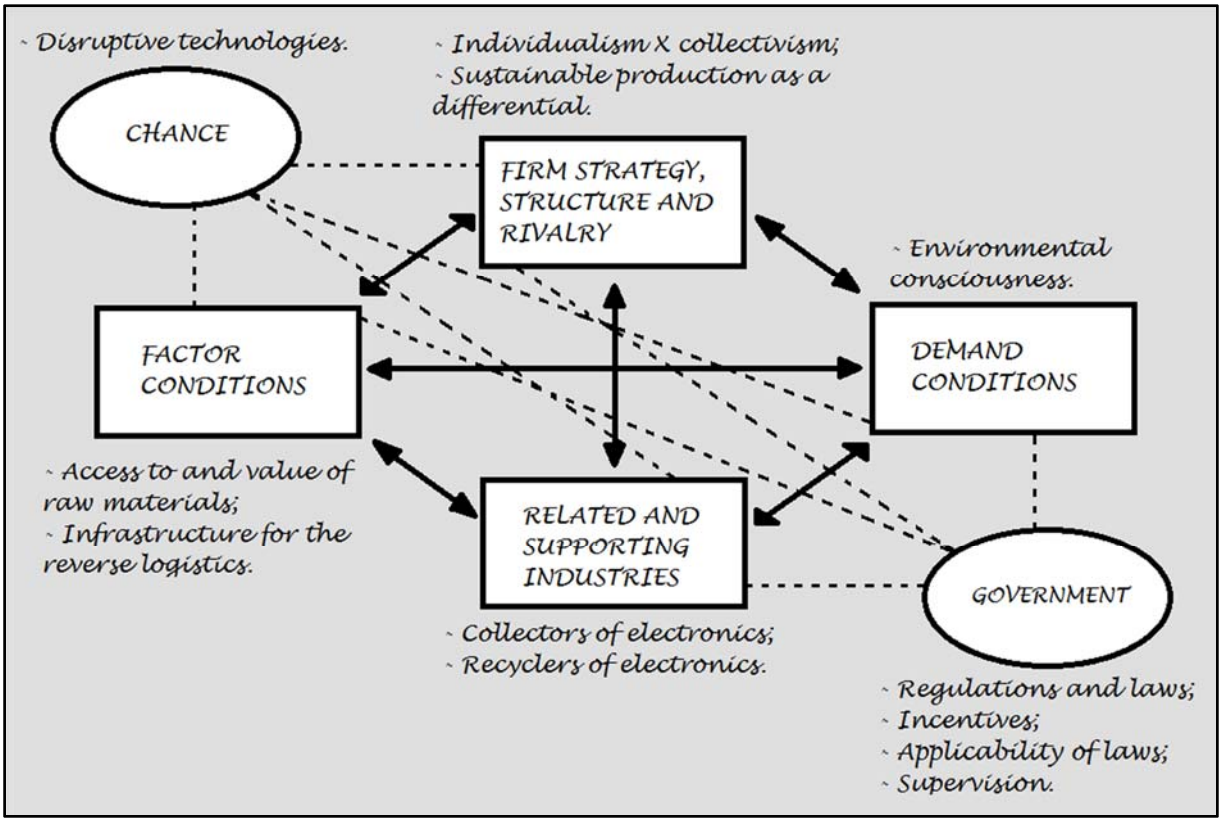
Finally, the last force presented by Porter's model is the threat of substitute products or services. With the recycling of electronics in mind, electronics more environmentally friendly could represent a threat for the existing ones. By investing in R&D for example, new electronics

could be appearing in the market with a more sustainable design, different components in their composition and easier ways of disassembly. Concerning services, more effective approaches towards collection and recycling of electronics could arise, representing a threat if the companies saw this material as a strategic asset.

As it may easily be observed from the current research, a series of factors influences the companies' strategies and actions towards the recycling of electronics. In addition, it has been possible to observe that the same manufacturers of electronics are adopting different strategies towards the recycling of electronics in the different scenarios analysed of Brazil and the United Kingdom. As such, the results from the case studies analysed in the global environment are directly connected with the Porter's diamond model discussed in the literature review.

The diamond model is applied to the global environment, as it determines the level of industries' competition according to their location. Especially when analysed in the global environment, with different realities depending on the location, such factors are evidently more complex than on the local scale. *Figure 19* exemplifies the Porter's diamond model applied to the specific case of the electronics' recycling.

Figure 19 - Porter's diamond applied to the recycling of electronics



Source: Developed by the author

One of the determinants of national advantage presented in the model is the firm strategy, structure and rivalry. Concerning the specific case of electronics' recycling, it is interesting to highlight the different approaches that may be taken in different environments, with an individualist X collectivist approach. As it has been pointed out, a series of collective measures have been applied within the European Union framework, which may bring valuable insights for the process. Considering the high complexity in which the recycling of electronics is involved, working together appears to bring better results than an individualist approach. In fact, just as highlighted in the interviews, the lack of sectoral agreements has been pointed out as one of the main hindrances in the Brazilian process.

Still in relation to the firm strategy, structure and rivalry, it is worth pointing out the sustainable production seen as a differential. Just as discussed in the literature review, the moment the companies start to look at sustainability as a way of profiting in a green manner is when they will evidently start to invest in more innovative ways to deal with the matter. Either being in more sustainable products from the design point of view or in better approaches for recovering/recycling the old electronics, the strategies should be different. Considering the distinct realities, it is possible that the perspective of the EoLs being a strategic asset in Europe is different from the one in Brazil.

Other determinant presented by the model are the factor conditions. In the specific case of the electronics, it is important to consider the access to and the value of the raw materials. By linking with what has been pointed out in the chapter *The European scenario*, the European Union has several programmes towards achieving a sustainable growth, with focus on the *Circular economy* discussed in the literature review. Just as presented in one of the European reports, raw materials have been increasing their values especially on the developed countries, where they have been hard to find. In addition, the same report points out that the recycling may also reduce the resources' dependence on other countries. Considering the abundance of some resources in Brazil if compared to Europe, this aspect also may play an important role in the way the strategy is designed.

Connected to the factor conditions is also the manufacturers' infrastructure towards the reverse logistics. One of the highlights is the difference of investments on a proper infrastructure between the European and the Brazilian scenario. Another highlight, which has been mentioned both in the chapter *Institutional and legal aspects for the management of electronic waste in Brazil* and in the interviews with the companies, is the territorial extension.

Considering the high extension of the Brazilian territory, the reverse logistics costs in Brazil are evidently higher than the European countries in general.

Just as presented in *Figure 19*, the demand conditions is another determinant of the Porter's diamond. In this sense, the consumers' environmental consciousness has a huge impact. Considering the population in one specific locality being highly environmentally conscious, this would pressure the industry to innovate and offer more sustainable products and services, either with services for properly discarding the electronics or with products that have a green design. If the population is not environmentally conscious, evidently that this does not pressure companies to adapt their approaches in this direction.

Another determinant for the competitiveness of a country, according to the diamond model, are the related and supporting industries. In the specific case of electronics, the collectors and the recyclers play an indispensable role. From the interviews, it has been possible to observe that the manufacturing companies having actions towards recycling of their products are working together with associations and recyclers entities to do so. As such, having such recyclers working with proper conditions is indispensable for the process to occur. Nevertheless, it has been identified in the interviews that there is not yet enough technology to do the whole process of electronics' recycling in Brazil. Without enough technology and infrastructure to complete the process, the printed circuit boards are usually exported to other countries. This prevents the company in national ground to make profit from this particular part, which has several precious metals and economic value.

In the case of Brazil, the waste collectors play an important part in the recycling process of recyclable waste in general. In the case of electronics, a proper qualification and awareness towards the dismantling of electronics and the importance of a proper handling can bring important results both for the process, by increasing the efficiency and for the collectors, by raising their income. In any case, both in Brazil and in Europe, the need of a qualified workforce for the recycling of electronics is high and the presence of collectors and recyclers with such knowledge could affect the whole system.

In addition to the four major determinants of national advantage, the diamond model also specifies two variables that may influence the system. One of these variables is chance, to which is worth pointing out to the disruptive technologies in the case of electronics. In this sense, technological breakthroughs from other companies such as new design, composition and dismantling characteristics may affect their competitiveness in the nation. It is possible that such technologies are not used by the same company in all the locations they operate, which could influence the strategy according to the country.

Finally, the other variable influencing the national system is government. In the case of the electronics, government seems to play a very important role. Since it is a costly process for the companies to embark on, special attention should be given to the regulations and laws in practice. In this case, there is the WEEE Directive and the RoHS Directive in Europe and the PNRS in Brazil. While both of the European Directives are from 2003, the PNRS is from 2010, which brings evidently a time gap in which Europe has been learning and improving its processes ahead of Brazil.

In addition to being recent, just as discussed in the interviews, much of what is proposed by the Brazilian law is not yet working in practice. Much more than the laws themselves, their applicability and supervision affect the system in the way companies respond to the obligations imposed. Another point, which is worth mentioning for the government variable, are the incentives. In the Brazilian case, besides the territorial extension, there are interstate taxes, which increase the reverse logistics costs if taken with a national approach.

As such, it is possible to observe that there is a series of determinants and variables influencing the recycling process, which definitely does not limit it to one single company. This variety of determinants and variables, applied with different views in the locations of Brazil and the United Kingdom, may explain why the companies' strategies diverge depending on their location.

7 FINAL CONSIDERATIONS

Taking into consideration the increasing importance of electronic waste management in Brazil and worldwide, the current research has had the main objective of studying about regulations and corporate strategies towards electronic waste recycling in Brazil and comparing it with the European context. Although multidisciplinary, such topic of research is directly linked with production engineering, as this particular engineering should be committed with sustainable production and design systems.

As such, the production engineering involves not only the process of production itself, but also the way it connects to the system as a whole. Therefore, aspects such as economy, logistics, environment and strategy are extremely linked with the ways a production system should be designed and implemented.

The research has taken many different methodological approaches in order to fulfill the following specific objectives:

a) To analyse the general European scenario concerning sustainability and electronic waste, in order to compare it with the Brazilian scenario;
b) To study the main regulations for the treatment of electronic waste in Europe and in Brazil;
c) To identify the main actors involved in the recycling process of electronics in Brazil;
d) To analyse how some of the main electronics' manufacturers inform on their websites about actions towards recycling of electronics in Brazil and in Europe;
e) To study about how some of the main electronics' manufacturers in Brazil are dealing with the recycling of electronics from both a strategic and operational point of view.

Concerning *objective a*, the section 4.1 brings the *The European Commission programmes towards a sustainable growth*, while section 4.2 talks about *The situation towards electronic waste in Europe*. The *Electronic waste scenario in Brazil* is presented in section 5.1.

Connecting with the literature review, some of the subjects discussed are the *Green economy and sustainable development* and the *Circular economy*. The main idea defended by the green economy is of attending the social and economic needs without disregarding the environment. The circular economy, which is directly connected to the previous concept, has the main aim of joining the concepts of zero waste, sustainability and economic growth, by designing circular systems of production where the residues are seen as resources that are put back into the system after the end-of-life, in order to close the loop.

All these ideals appear in the programmes organized by the European Commission discussed in section 4.1, especially the circular economy model. Among the main programmes from the European Commission identified towards a sustainable growth there is *The Europe 2020 Strategy*, which is the European Union's growth strategy for improving the resource efficiency; and the 7th EAP, which gives a special focus to the circular economy model.

While Europe in general is clearly ahead of Brazil in many aspects concerning the electronic waste scenario, it is interesting to highlight that even in Europe there is a lot yet to be improved. Besides, there are big differences in the current scenario of electronic waste among the European countries. While some, with highlights to Sweden and Norway, show evidently the highest rates of electronics' collection in Europe, other countries do not evidence such a good performance. In terms of Brazil, it is interesting to mention about the rapidly growing consumption of electronics, such as the estimation that there will be one computer for every person in the country until 2017 (FGV, 2015). Considering the high population, the amount of electronic waste generated in Brazil tends to be considerable.

Objective b is studied in section 4.3 for Europe, with *The European legislations towards electronic waste*. The *Legal framework for the management of electronic waste in Brazil* in section 5.2 complements the objective. The *Identification of the main actors involved in the recycling of electronics in Brazil*, which is *objective c*, is in section 5.3.

When studying about legislation for the electronic waste, it is interesting to bring back the section of *Electronic devices and electronic waste* from the literature review. As such, this section discusses about the composition of electronic devices, with a focus in the recycling process of electronic waste and its environmental impacts. It is important to consider that this particular waste, just as presented in the literature review, has a series of characteristics that makes it extremely harmful to the environment if not being correctly treated, which should be different from the treatment of regular waste.

In terms of legislation in Europe, there are two Directives from the European Union to deal with the electronic waste, which should be applied by all the European Member States. The WEEE Directive was approved in 2003 and has had many versions since then. It is based on the principle of the extended producer responsibility, also settling collection targets. The other directive is the RoHS Directive, also from 2003, establishing that some hazardous substances should be phased out from the production of electronics.

The legislation in Brazil concerning electronic waste relies currently on the *National Solid Waste Policy* (PNRS). This policy is from 2010 and, although not specific for the

electronic waste, has some chapters addressing the subject. Just as the WEEE Directive, the PNRS is also based on the principle of the extended producer responsibility.

The PNRS, although relevant, has many points not yet working in practice. Among the hindrances in the recycling process found on the secondary data analysis, there is the need of qualifying the collectors for the specific case of electronic waste. The lack of infrastructure and technology, which prevents the country from doing the entire recycling process of electronics; in addition to the obstacle of the interstate taxes, making the process even more expensive than it already is, are also discussed.

A series of actors have been identified in the recycling of electronics in Brazil, which evidences the high level of complexity in which it is involved. Among many, there is the a high number of municipalities that should participate in the recycling process; the Ministry of Environment; associations such as ABINEE, ABREE, ELETROS and CEMPRE, the distributors, importers, retail business, the recycling companies, the technical assistance shops and the recycling cooperatives.

By going back to the literature review concerning *Green economy and sustainable development,* it is discussed some of the possible hindrances in adopting the green model, in addition to the need of an approach taken collectively with the diverse actors involved. Just as discussed by UNEP, the green economy model should be relevant to all economies, independently of political views and governmental approaches.

Objectives d and *e* are related to the companies' strategies towards the recycling of electronics, which are studied in chapter 6, with the case studies. Section 6.1 brings a *Website analysis* of some of the main electronics' manufacturers in Brazil, besides a further comparison of the information provided by the same companies on the websites of Brazil and of the United Kingdom. Therefore, such section is in line with *objective d*, analysing the Brazilian and the European scenario for some of the main electronics' manufacturers. Finally, section 6.2 brings the *Strategy of the "mysterious client"* and section 6.3 brings *The interviews*, so that to be in line with *objective e*.

The *Website analysis* is divided into two parts, namely *The Brazilian websites* and *A comparison with the European websites*. In the first part, the Brazilian websites of the ten major notebook manufacturers in Brazil are analysed. From that, it has been possible to observe that most of the companies do not have all the information concerning sustainability issues in Portuguese. Concerning the specific guidelines for electronics' disposal, most of them do not have a direct link for this information on their homepages, while some do not have any information on the matter. Therefore, it is possible to connect such actions with the literature

review dealing with *Strategy for the reverse logistics and recycling of electronics*. As it has been observed, some companies are not perceiving the electronics' recycling as an opportunity to be part of the company's strategy of differentiation in the market. Instead, some perceive it as a threat, thus moving actions only to obey laws and regulations.

Still in regard to the website analysis and making a connection with the section from the literature review about *Reverse logistics of electronic waste*, it has been possible to observe that the companies are adopting different approaches towards the matter of collection and logistics. Among the companies that have information in this regard announced on their websites, some recommend the customer to deliver the product at technical assistance points, while others ask the customer to fill an online form for the recycling free of charge. Some other companies in Brazil ask the customer to send an e-mail or call the customer service for further guidelines.

By contacting the customer service support of the same companies in Brazil, it has been applied the *Strategy of the "mysterious client"*. The researcher, pretending to be a customer wishing to discard its electronic, has demanded the company how to proceed. With that, it has been possible to compare the information provided on the websites with the information from the customer service support. Two of the ten companies have provided different information on the customer service support from the information provided on the company's website. In addition, four have informed on the phone not to have any service or collection point provided for the discard of their products. This indicates that, although some companies are clearly moving efforts towards the collection of electronics after the end-of-life, some are clearly not yet prepared to deal with the issue.

The second part of the *Website analysis* brings *A comparison with the European websites*. As such, the eight companies from the list that are present worldwide have been analysed by comparing the information given to the customers in Brazil and in the United Kingdom. It has been possible to observe that all the companies in the UK have webpages dealing with sustainability issues, just as all have a link for the information about the electronics' discard. In addition to the scenario being better in the companies on the UK than the companies in Brazil, it has been possible to observe that most companies are not applying the same approaches in the different countries. This could, for example, be due to the different laws in practice, the hindrances in the process and the strategy being taken.

The last part of the research brings *The interviews* conducted with ABREE, two companies and one recycling partner of another company from the list of the ten major notebook manufacturers in Brazil. Concerning the process, it has been possible to identify that the companies are dealing with it in different ways, from collection to recycling process. For the

dismantling part, the process is done either mechanically or manually and, as there is not enough technology to recycle the printed circuit boards, most companies export them. While the recycling company and ABREE believe that the process of electronics' recycling could be profitable in the country, both manufacturing companies do not.

Another point highlighted in the literature review is the *Innovation and uncertainties in the recycling of electronics*. From the systematic literature review, the main uncertainties identified in the e-waste recycling business are the following: Different recycling technologies; unknown environmental impacts; different product design and composition; unknown reverse logistics costs; variable cost of recycling; rapidly changing nature of electronics; unpredictability about return of items concerning quantity, quality and timing; unknown destination of WEEE; different value of scrap materials; competition between the manufacturer and the remanufacturer; no common legislation at the national and global level; outdated political aspects; and complexity of regulations.

The main adversities and uncertainties pointed out in the interviews concerning the recycling process of electronics in the country are: The cost model; the fiscal policy; the lack of residues' classification and regulations on the PNRS; the lack of recyclers, the lack of environmental consciousness; and the lack of studies about WEEE and its quantities. All these different highlights, although looked from different perspectives, give a broad idea about the complexity of the electronics' recycling.

Dealing specifically with the PNRS, the companies have mentioned several gaps, such as the tax law, collection points, random targets and the shared responsibility. In addition, the sectoral agreements have been pointed out as a possible solution to a series of hindrances, while the education and the definition of rules could be improved. Besides, as discussed in many parts of the research, it has also been mentioned the need of a collective approach for the reverse logistics and the recycling of electronics truly work.

7.1 Limitations of the present work and suggestions for further research

The research conducted has had an exploratory nature, in order to bring insights about a subject considerably new and on high demand of specialization. As a variety of actors is involved in the recycling process, which is highly complex, the present analysis does not comprehend a complete tool for analysis, but instead one for bringing insights on the subject.

The research has had the main goal of studying about regulations and corporate approaches towards electronic waste recycling in Brazil and to compare it with the European

context. It has analysed the public and corporate sphere with more detail than the consumer side. Evidently, the electronic waste management is highly complex and involves a variety of actors. Thus, it is suggested future research to be conducted about the other actors involved, such as studying about the consumers' participation on such issue, which also play an important part.

One path suggested, in order to study the consumer sphere, is to conduct surveys and/or interviews with the population. Subjects that could be further discussed are to measure the level of consumer's awareness on the importance of having a different disposal for the electronic waste from the regular waste; and/or to study about the consumer's knowledge about how to manage the electronic waste and the location of collection points.

For the analysis on the companies' websites, it has been analysed the websites of certain companies in Brazil and in the UK. The UK has been chosen due to language issues, in order to have a broad idea of the European scenario. Nevertheless, although there are common regulations for the European member States, each country has different approaches towards the subject of electronics' recycling. Therefore, the results from the analysis on the websites of the companies in the UK cannot be generalized to the entire European scenario, but instead bring an idea for comparison with the Brazilian scenario. It is thus suggested further research on the companies' websites of different countries in Europe, so that to identify main similarities and differences among them.

As the research conducted has been of a qualitative nature and few cases have been analysed, it is not possible to generalize the results. Therefore, it is suggested further research of quantitative nature, such as surveys with the electronics' manufacturers or recycling companies in Brazil, in order to identify their behavior in the market on a large scale.

Further, the research has had a focus at the national level when studying the case of Brazil. Due mostly to time and financial constraints, it has not been possible to deeply study all actions in a small scale in the country. Being so, another suggestion for further research is to study approaches in different levels, like at the state or municipal level, as well as the communication among them.

A suggestion for a Doctoral research is to build a platform with the main information about electronic waste in Brazil. Such platform could identify all the collection points, as result of the joint research with companies. In addition, it could gather information about laws and governmental practices, as well as raising awareness in the population about the importance of a proper disposal. Therefore, the result of such research could serve as the main tool for obtaining information about electronic waste in the country.

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APPENDIX A - INTRODUCTION LETTER FOR THE INTERVIEWS (ORIGINAL VERSION)

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

PRO

CARTA DE APRESENTAÇÃO

Caro _____,

Sou administradora de empresas, mestra em Engenharia de Planejamento e Sustentabilidade (Polytech Tours, França) e atualmente mestranda do Programa de Pós-Graduação em Engenharia de Produção da Escola Politécnica da USP.

Sob orientação do prof. Mario Sergio Salerno, professor titular da USP e Coordenador do Laboratório de Gestão da Inovação (LGI) e do Observatório da Inovação e Competitividade (NAP), minha dissertação na USP estuda abordagens de gestão de resíduos eletroeletrônicos. Ela busca analisar as principais questões legais em vigor, além das estratégias corporativas quanto à reciclagem dos eletroeletrônicos no Brasil.

Parte fundamental da pesquisa envolve entrevistar empresas fabricantes de eletroeletrônicos de forte presença no Brasil, com vias a analisar como lidam com a questão em termos práticos e estratégicos. As informações obtidas farão parte da minha dissertação e, possivelmente, de artigos acadêmicos.

Nesse sentido, peço encarecidamente sua resposta ao questionário a seguir. Sua resposta, além de indispensável para o sucesso da pesquisa, possibilitará uma análise mais aprofundada do cenário empresarial na questão da reciclagem de eletroeletrônicos no Brasil, buscando a identificação dos principais gargalos e focos para aprimoramento futuro.

Grata desde já e à disposição para eventuais dúvidas,

Alice Frantz Schneider
alice.afs@usp.br
tel: +55 (xx) xx xx xx xx

www.pro.poli.usp.br
Av. Prof Almeida Prado , travessa 2 , nº 128 - - 05508-070 - Cid Universitária
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APPENDIX B - INTRODUCTION LETTER FOR THE INTERVIEWS (TRANSLATED VERSION)

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

PRO

PRESENTATION LETTER

Dear _____,

I have a bachelor in Business Management, master's degree in Planning and Sustainability Engineering (Polytech Tours, France) and I am currently a master student of the Graduate Program in Production Engineering at the Polytechnic School of USP. Under the guidance of prof. Mario Sergio Salerno, full professor at USP and coordinator of the Innovation Management Laboratory (LGI) and the Innovation and Competitiveness Observatory (NAP), my dissertation at USP studies approaches for electronics waste management. It seeks to analyze the main legal issues into force, in addition to corporate strategies regarding the recycling of electronics in Brazil.

An essential part of the research involves interviewing manufacturing companies of electronics with strong presence in Brazil, as a way to analyze how they deal with the issue in practical and strategic terms. The information obtained will be part of my dissertation and possibly academic articles.

In this regard, I kindly ask your answer to the following questionnaire. Besides being indispensable for the success of the research, your answers will enable a more detailed analysis of the business scenario concerning the recycling of electronics in Brazil, by seeking to identify the major bottlenecks and focus for future improvement.

Gratefully and available for any possible questions,

Alice Frantz Schneider
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APPENDIX C - QUESTIONNAIRE ABREE (ORIGINAL VERSION)

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

PRO

QUESTIONÁRIO

1. Favor descrever quais atividades a ABREE exerce perante seus associados para a gestão do resíduo eletroeletrônico.

Resposta:

2. A ABREE terceiriza alguma de suas atividades de logística reversa? Em caso positivo, qual (quais)?

Resposta:

3. Como acontece a coleta do resíduo eletroeletrônico pela ABREE?

Resposta:

4. Qual o território que a ABREE abrange para a coleta?

Resposta:

5. Como é o processo de separação das peças eletroeletrônicas feito pela ABREE?

Resposta:

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Tel.: 55 11 3091-5363 – fax 3091-5399 – São Paulo – SP - Brasil

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

PRO

6. Como acontece a destinação final/reciclagem dos eletroeletrônicos pela ABREE?

Resposta:

7. A ABREE exporta alguma peça dos resíduos eletroeletrônicos ou realiza todo o processo de reciclagem em solo nacional? Em caso de exportação, qual (quais) peças?

Resposta:

8. A ABREE acredita que o processo completo de reciclagem de resíduos eletroeletrônicos pode ser um negócio rentável no Brasil?

Resposta:

9. Qual a influência dos parceiros da ABREE (Eletros, ERP e Eletrolar) sobre o processo?

Resposta:

10. Em relação à Política Nacional de Resíduos Sólidos (PNRS), tem alguma crítica e/ou sugestão do que poderia ser melhorado?

Resposta:

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Tel.: 55 11 3091-5363 – fax 3091-5399 – São Paulo – SP - Brasil

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

11. Quais principais adversidades/incertezas que a ABREE considera existir no processo de reciclagem dos eletroeletrônicos no Brasil? Alguma sugestão de como melhorá-lo?

Resposta:

12. A ABREE possui alguma ferramenta/iniciativa de comunicação e informação ao público para o descarte adequado dos eletroeletrônicos ao final da vida útil? Qual (quais)?

Resposta:

13. Em relação às empresas de eletroeletrônicos no Brasil que não são associadas à ABREE, tem alguma informação de como realizam o processo de logística reversa de seus produtos?

Resposta:

Espaço para comentários:

www.pro.poli.usp.br
Av. Prof Almeida Prado , travessa 2 , nº 128 - - 05508-070 - Cid Universitária
Tel.: 55 11 3091-5363 – fax 3091-5399 – São Paulo – SP - Brasil

APPENDIX D - QUESTIONNAIRE ABREE (TRANSLATED VERSION)

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

PRO

QUESTIONNAIRE

1. Please describe what activities ABREE carries out towards its members for the management of electronic waste.

Answer:

2. Does ABREE outsource any of its reverse logistics activities? If so, which one (s)?

Answer:

3. How is the collection of electronic waste done by ABREE?

Answer:

4. Which territory ABREE covers for collection?

Answer:

5. How is the process of separating the electronic pieces made by ABREE?

Answer:

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Av. Prof Almeida Prado , travessa 2 , nº 128 - - 05508-070 - Cid Universitária
Tel.: 55 11 3091-5363 – fax 3091-5399 – São Paulo – SP - Brasil

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PRO

6. How is the process of disposal/recycling of electronics made by ABREE?

Answer:

7. Does ABREE export any piece of electronic waste or does it do all the recycling process on national soil? In case it exports, which piece(s)?

Answer:

8. Does ABREE believe that the complete process of electronic waste recycling may be a profitable business in Brazil?

Answer:

9. What influence do the ABREE's partners (Eletros, ERP e Eletrolar) have on the process?

Answer:

10. Regarding the National Solid Waste Policy (PNRS), do you have any critics and/or suggestions of what could be improved?

Answer:

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11. What does ABREE consider as the main adversities/uncertainties in the recycling process of electronics in Brazil? Any suggestions on how to improve it?

Answer:

12. Does ABREE have any tools/initiatives of communication and information for the public about a proper disposal of electronics at the end of life? Which one(s)?

Answer:

13. Regarding the electronic companies in Brazil that are not associated with ABREE, do you have any information on how they perform the reverse logistic process of their products?

Answer:

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APPENDIX E - QUESTIONNAIRE FOR THE COMPANIES (ORIGINAL VERSION)

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PRO

QUESTIONÁRIO

Nome do respondente: _____

Nome da empresa: _____

Cargo / função do respondente: _____

1. A empresa realiza alguma atividade para o gerenciamento do resíduo eletroeletrônico que comercializa? Em caso positivo, favor especificar as atividades realizadas em sequência, desde a coleta do aparelho ao final da vida útil até a destinação final.
   (No caso de a atividade ser realizada por outra instituição que não a empresa, favor especificar a instituição e atividade relacionada).

Resposta:

2. Considerando que a empresa realize a coleta de aparelhos ao final da vida útil, como é feito esse processo?

Resposta:

3. Considerando que a empresa realize a separação das peças e destinação final, como são feitos tais processos?

Resposta:

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PRO

4. Em relação à separação das peças e considerando a alta complexidade envolvida, há peças que não são recicladas no Brasil? Em caso positivo, quais e qual é o destino delas?

Resposta:

5. A empresa está ligada a alguma instituição com o propósito de gerenciar os resíduos eletroeletrônicos? Em caso positivo, qual (quais)? Há algum monitoramento dessas atividades pela empresa?

Resposta:

6. Caso haja atividades hoje terceirizadas para a gestão do resíduo eletroeletrônico, a empresa considera realizá-las por conta própria no futuro? Por quê?

Resposta:

7. A empresa acredita que o processo completo de reciclagem de resíduos eletroeletrônicos pode ser um negócio rentável no Brasil?

Resposta:

8. Em relação à Política Nacional de Resíduos Sólidos (PNRS), tem alguma crítica e/ou sugestão do que poderia ser melhorado?

Resposta:

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PRO

9. Quais você considera como sendo as principais adversidades/incertezas no processo de reciclagem dos eletroeletrônicos no Brasil?

Resposta:

10. A empresa possui alguma ferramenta/iniciativa de comunicação e informação ao público para o descarte adequado dos eletroeletrônicos ao final da vida útil? Qual (quais)?

Resposta:

11. Que políticas voltadas à sustentabilidade a empresa possui?

Resposta:

Quanto à divulgação das informações aqui fornecidas, favor escolher a opção de preferência.

a. Autorizo a divulgação ao público das informações que forneci aqui para fins de dissertação e possíveis artigos acadêmicos, juntamente com a identificação da empresa e meu nome associados às respostas.

b. Autorizo a divulgação ao público das informações que forneci aqui para fins de dissertação e possíveis artigos acadêmicos, mantendo em sigilo o nome da empresa e meu nome associados às respostas.

Espaço para comentários:

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APPENDIX F - QUESTIONNAIRE FOR THE COMPANIES (TRANSLATED VERSION)

Escola Politécnica da Universidade de São Paulo
Departamento de Engenharia de Produção

PRO

QUESTIONNAIRE

Respondent's name: _____

Company's name: _____

Respondent's position / function: _____

1. Does the company conduct any activity for the management of electronic waste commercialized? If so, please specify the activities carried out in sequence, from the collection of the appliance at the end of life to the final disposal.
   (In case the activity is carried out by an institution other than the company, please specify the institution and related activity).

Answer:

2. Considering that the company carries out the collection of devices at the end of life, how is this process done?

Answer:

3. Considering that the company carries out the separation of pieces and final disposal, how are these processes made?

Answer:

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4. Regarding the separation of pieces and considering the high complexity involved, are there pieces not recycled in Brazil? If so, which ones and what is their destination?

Answer:

5. Is the company linked to any institution for the purpose of managing electronic waste? If so, which one(s)? Is there any monitoring of these activities by the company?

Answer:

6. In case there are today outsourced activities for the management of electronic waste, does the company consider performing them on their own in the future? Why?

Answer:

7. Does the company believe that the entire process of electronic waste recycling can be a profitable business in Brazil?

Answer:

8. Regarding the National Solid Waste Policy (PNRS), do you have any critics and/or suggestions of what could be improved?

Answer:

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PRO

9. What do you consider the main adversities/uncertainties in the recycling process of electronics in Brazil?

Answer:

10. Does the company have any tools/initiatives of communication and information for the public about a proper disposal of electronics at the end of life? Which one(s)?

Answer:

11. What kind of policies does the company has focused on sustainability?

Answer:

Concerning the disclosure of information provided here, please choose the option preferred.

a. I hereby authorize the public disclosure of the information I provided here for the purpose of dissertation and possible academic articles, together with the identification of the company and my name associated with the answers.
b. I hereby authorize the public disclosure of the information I provided here for the purpose of dissertation and possible academic articles, keeping the identification of the company and my name associated with the answers confidential.

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