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Research Master Planning and Sustainability:

Urban and Regional Planning

Urban planning approaches for electronic waste management

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Urban planning approaches for electronic waste management

Abstract:

An important part of the urban planning is the management of waste. While the regular waste already represents a huge concern, with the electronic waste is not at all different. Considering the extremely relevant topic, the starting question for this research is the following: How do urban planning approaches deal with the electronic waste management in different contexts? The work is divided in two parts. Part I brings the literature review about green economy and sustainable development; circular economy; urban metabolism; strategic spatial planning; and institutional change and collective learning. It also highlights the European scenario, focusing on the European Commission programmes toward a sustainable growth, then presenting the European legislations toward electronic waste and outlining the situation in Europe. Based on secondary data, Part II is composed of the case studies of Sweden, France and Brazil. The main objective has been to promote a study about the urban planning approaches toward the electronic waste management in these three countries. The specific objectives have been to analyze the current actions; to identify key problems in the process; to compare the scenario in the three countries; and to propose possible actions for improvement. The ecological footprint and the e-waste scenario in each country are presented, followed by a study on the management of the e-waste and the identification of the main actors involved in each case. A comparative analysis with specific aspects from all case studies is made in the end.

Keywords: circular economy, green economy, institutional proximity, recycling system, strategic spatial planning, sustainable development, urban metabolism, waste electrical and electronic equipment.

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Abordagens de planejamento urbano para gestão de resíduos eletroeletrônicos

Resumo:

Parte importante do planejamento urbano é a gestão de resíduos. Enquanto que o resíduo comum já é uma grande preocupação, o lixo eletroeletrônico não é de modo algum diferente. Considerando o tema extremamente relevante, a pergunta de partida para esta pesquisa é a seguinte: Como as abordagens de planejamento urbano lidam com a gestão de resíduos eletroeletrônicos em diferentes contextos? O trabalho está dividido em duas partes. A Parte I traz a revisão da literatura sobre economia verde e desenvolvimento sustentável; economia circular; metabolismo urbano; planejamento estratégico territorial; e mudança institucional e aprendizagem coletiva. Também destaca o cenário europeu, com foco nos programas da Comissão Europeia em busca de um crescimento sustentável, em seguida apresentando a legislação Europeia em relação ao lixo eletroeletrônico e expondo a situação na Europa. Baseada em dados secundários, a Parte II traz os estudos de caso da Suécia, França e Brasil. O principal objetivo foi o de promover um estudo sobre as abordagens de planejamento urbano para a gestão de resíduos eletroeletrônicos nos três países. Os objetivos específicos foram de analisar as medidas em vigor; identificar os principais problemas no processo; comparar o cenário nos três países; e propor possíveis ações de melhoria. A medida 'ecological footprint' e o cenário de resíduos eletroeletrônicos em cada país são apresentados, seguido de um estudo sobre a gestão do lixo eletroeletrônico e da identificação dos principais atores envolvidos em cada caso. Uma análise comparativa com aspectos específicos de todos os estudos de caso é feita ao final.

Palavras-chave: economia circular, economia verde, proximidade institucional, sistema de reciclagem, planejamento estratégico territorial, desenvolvimento sustentável, metabolismo urbano, resíduos de equipamentos eletroeletrônicos.

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

(Herman Mulder apud EMF, 2012, p. 84)

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ACKNOWLEDGEMENTS

Willing to build an international career, I have always believed that living in a strange environment and meeting people with different cultures and backgrounds was the first step for achieving my goal. Studying in a different country has been my dream for many years and I would like to express my extreme gratitude to the ones that made it possible.

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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 everyday.

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), may 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, as it is demonstrated in *Appendix A*, which shows some of the potential hazards of e-waste on human beings. 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.

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 planning approaches for the subject, a more detailed study about it is of extreme importance. Therefore, comparing how the process is done in different scenarios could bring insights for new approaches to be taken from all different actors involved in the process: from companies' practices to governmental planning policies.

Starting question

Considering the extremely relevant topic of electronic waste, which is on growing demand today, this Research Master Thesis has, as its main goal, to draw some insights on the subject, so that to improve the electronic waste recycling systems. As the subject is extremely multidisciplinary, although it will be dealt with the most holistic view possible, a special focus will be given to the planning field.

Accordingly, the starting question has been elaborated as the following:

How do urban planning approaches deal with the electronic waste management in different contexts?

Global research structure

The research has an exploratory nature, with the aim of developing new theoretical and empirical insights about the topic, which is still incipient within the academic sphere.

In line with the main goal and starting question, the research is structured in two parts. *Part I* has three chapters and is entitled as *Literature review and the European scenario*. *Chapter 1* is composed of the literature review about the following subjects: green economy and sustainable development; circular economy; urban metabolism; strategic spatial planning; and institutional change and collective learning. *Chapter 2*

brings the European Scenario, focusing on the European Commission programmes toward a sustainable growth, then presenting the European legislations toward electronic waste and then, finally, outlining the situation towards electronic waste in Europe. *Chapter 3* then presents some final remarks from *Part I*.

Part II, entitled *Institutional settings toward the management of waste electrical and electronic equipment: foundations and lessons from the Swedish, French and Brazilian case*, is composed of the case studies. The first chapter of *Part II* explains why the specific countries have been chosen for analysis, as well as highlighting the main and specific objectives of the research and describing the research methodology for the case studies.

Then, each chapter brings the case study of every country analyzed separately. The ecological footprint and the electronic waste scenario in each country are presented, followed by a study on the management of the electronic waste and the identification of the main actors involved in each case. Final considerations are drawn up in the end of each chapter of the case studies and a table enlightening specific aspects is presented. The last chapter of *Part II* brings the final considerations, with a global analysis on all the case studies, in order to compare them as a possible way of bringing insights in developing more efficient planning approaches for the electronic waste management.

The last two chapters of the research present final considerations of the entire work, as well as pointing out to some important aspects that have not been addressed and giving suggestions of further research to be conducted.

The Swedish system analysis, together with the study about circular economy, the European Commission programmes and the need for an institutional change have been part of a paper presented by Schneider and Hamdouch (2015) at the *8th International Conference on Proximity* held in Tours, France from 20-22 May 2015.

PART I

LITERATURE REVIEW AND THE EUROPEAN SCENARIO

Part I is divided in mainly two sections. The first section brings the literature review concerning five subjects. Firstly, it is studied the concept of green economy and sustainable development, as well as connecting them with their role in the planning systems. Secondly, the circular economy is analyzed, bringing some insights from the Ellen MacArthur Foundation. Urban metabolism is studied next, as a way of identifying the flows of energy and materials in the cities' environment. The strategic spatial planning is dealt further, as it is directly linked with the collection and treatment of waste planning systems. Finally, the last section talks about institutional change and collective learning, as it is believed that both are necessary to achieve high levels of proximity among actors and, thus, a high level of efficiency in the process.

The second section of *Part I* brings the European scenario. The European Commission has a number of programmes toward a sustainable growth and some of these main programmes are studied further. Secondly, the European legislations toward electronic waste are analyzed. Lastly, the situation of the electronic waste in Europe is presented.

1 LITERATURE REVIEW

1.1 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 the 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 et al, 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 et al. (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 other way 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 et al., 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 in 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 et al, 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 and 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 may boost economic growth. 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, to 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". From this quote, it is possible to identify the importance

of a collective approach, which will be treated further the topic *1.5 - Institutional change and collective learning*, and to which involves a high level of commitment from different actors, especially from the government.

According to UNEP (2011), although the green economy model may 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 1 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 1*, 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 (*Figure 1*) to work in direction to a green economic development.

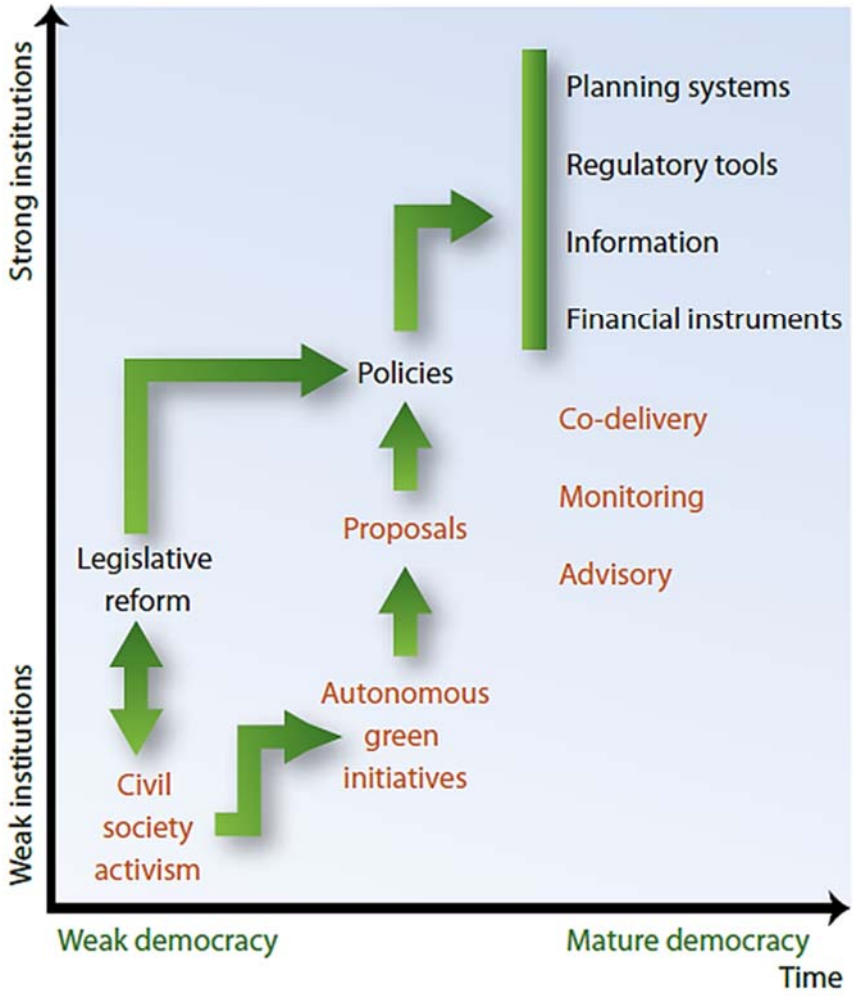

Figure 1: Enabling conditions, institutional strength and democratic maturity

(Source: UNEP, 2011, p. 474)

A measure that is directly linked to the goals of a green economy is the ecological footprint. According to the Global Footprint Network (2010, p. 4):

> The Ecological Footprint measures the area of biologically productive land and water required to provide the resources used and absorb the carbon dioxide waste generated by human activity, under current technology. Accounting for a country's consumption Footprint starts with all goods and services produced in that country, then adds imports and subtracts exports.

The report complements that usually the analysis is made by comparing the country's footprint with its biocapacity, which means "the area of productive land and water available to produce resources or absorb carbon dioxide waste, given current management practices" (Global Footprint Network, 2010, p. 4).

By comparing a country's ecological footprint with its biocapacity, it is possible to have a proper understanding of each scenario. Both measures are given in the same unit, which is global hectares, or gha. "One gha represents a hectare of forest, cropland, grazing land or fishing grounds with world average productivity" (Global Footprint Network, 2010, p. 4).

UNEP (2011) states that many countries, especially the most developed ones that have a high level of human development, also have a large ecological footprint. On the other hand, countries that have a small footprint usually also have a low level of human development, with many problems with basic services, like education and health. In this sense, one of the biggest challenges in the present economy, to what concerns environment, is to achieve a high level of human development, while at the same time having a small ecological footprint, or the least possible footprint in comparison with its biocapacity. The relation between ecological footprint and biocapacity will be analyzed further for the countries of Sweden, France and Brazil in the section of the case studies.

McCormick et al (2015) point out to the fact that there is a variety of concepts related to the green economy concept, 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. The concept of green jobs, widely addressed by the European Commission programmes that will be treated further in the *Section 2.1 - The European Commission programmes toward a sustainable growth*, defends that improving the environmental sector may have very significant and positive results by generating new job opportunities.

Another concept related to green economy, which is probably the most notable one, is sustainable development (McCormick et al, 2015). The concept of sustainable development already existed in the 1980's and started to be more widely used after 1987, with the World Commission on Environment and Development (WCED) report (Barbier and Markandya, 2012; Fiorino, 2014). Sustainable development is defined, according to

the WCED report (apud Barbier and 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”.

According to Pearce et al. (1989), the term *development* may be seen, especially in the economy 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 et al., 1989).

In the same sense, another important point to discuss is the difference between sustainable development and territorial development. According to Albrechts et al. (2003), while sustainable development represents a strategy of combining social, economic and environmental practices, territorial development is the translation of the concept into regulatory practices and investment programmes.

Sustainable development is a subject that has been gaining a lot of focus for the last years. Although countries have adopted legislation to integrate plans with it, Berke and Conroy (2000) argue that the extent to which plans promote this concept is yet unknown. With that in mind, they analyzed if plans that integrate the concept have a better advance in relation to sustainability principles in comparison to plans that do not. In order to discover that, they evaluated 30 plans according to a set of six principles that define the concept of sustainable development, which were: harmony with nature; livable built environment; place-based economy; equity; polluters pay; and responsible regionalism.

Berke and Conroy (2000) concluded with their research that there was not a considerable difference between plans that integrate the concept and the ones that do not, which raises the question of to what extend the concept of sustainable development is really important when it comes to planning. One explanation could be that, although *code words* for the concept may not be politically accepted in some places, the principles are

of common sense. Other explanation presented is that old planners are not used to the sustainability concept. Another result was that plans did not have a balanced support between the six principles. Instead, they were more focused on the livable built environment. Consequently, other principles received less attention, especially polluters pay and responsible regionalism.

According to Berke and Conroy (2000), one of the main criticisms concerning the subject of planning for sustainable development is the idea of sustainable development as only a fad in planning. They further argue that, unless the planning field starts to create more connected plans that truly benefit community in sustainability aspects, the critics will be right. From their study, some concerns that have been raised for future planning approaches were to try finding ways in creating more connected plans toward sustainability issues, besides trying to identify expansive directions that should be taken to narrow the gap between theory and practice.

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.

1.2 Circular economy

In the traditional view of economic growth, the system is seen as linear. According to EMF (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” (EMF, 2012, p.14). Therefore, more 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 many negative impacts on companies’ environment. Especially today, natural resources are becoming scarce with the exaggerated consumption as compared to limits of the planet. Also, just as the urban population increases, so do the costs for extraction, especially due to logistics costs of farther locations.

When analyzing 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 and Depret, 2010, 2012; Depret and Hamdouch, 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” can allow companies to directly draw on new business opportunities offered by new technologies and, indirectly, and through enhancing the company’s image as it supports a sustainable development approach, help those engaged in this strategic approach attract more clients. As a result, an increasing number of companies is introducing preventive approaches and looking at the environmental preservation as a business opportunity nowadays (Hamdouch and Depret, 2010, 2012; Depret and Hamdouch, 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 one of the most powerful (EMF, 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, as 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 of 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, the circular system connects the use of resources with the waste of residuals.

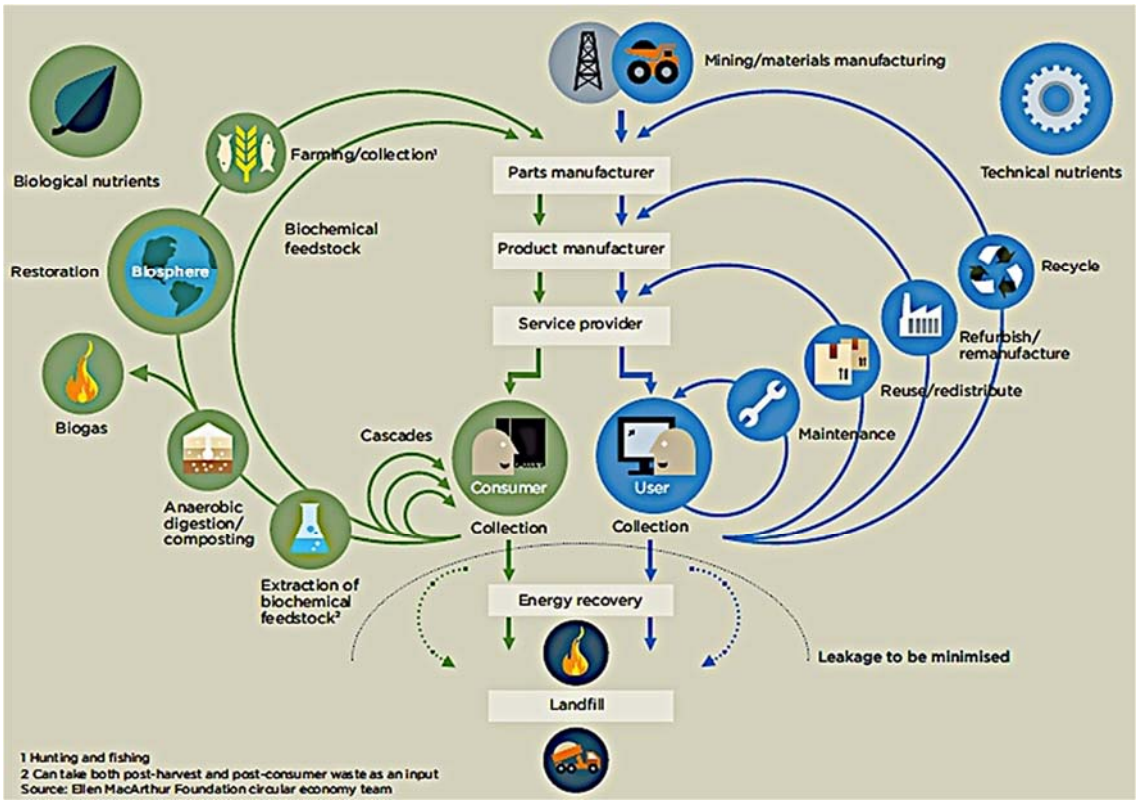

Figure 2: The material flow in the circular economy

(Source: EMF, 2012, p.24)

The Ellen MacArthur Foundation (2012) reinforces the concept by affirming that it is regenerative by both intention and design, which is demonstrated in *Figure 2*. Further, they affirm 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 (EMF, 2012, p.07).

Taken as such, these statements induce that the concept of circular economy may seem simple. However, when it comes to the implementation of such precepts or principles apparently (and genuinely) deriving from wisdom, 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. As it will be emphasized later in section *1.5 - Institutional change and collective learning*, divergence 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, can help in the process for shifting to a new approach, as exemplified by the role played by the European Commission, which will be presented in chapter 2 - *The European scenario*.

1.3 Urban metabolism

In the urban environment, every place, such as a city, has a series of complex structures that differentiates it from the others, like social, cultural and economic aspects, size, geographical location and infrastructure. Thus, each environment represents a different reality and, as such, has different needs and develops in different manners.

The urban metabolism idea has deep roots in the sociology, having Karl Marx as one of the first scholars to discuss it. In 1883, he "used the concept of metabolism to describe the material and energy exchanges between nature and society in his critique of industrialization" (Zhang, 2013, p. 463). With the extremely fast urban expansion and the evident consequences on the environment, the concept of urban metabolism started to gain strength. According to Kennedy et al (2007), a pioneering article about this concept appeared in 1965 from Wolman, as a response of the reduction in the environmental quality of certain aspects in some cities from United States.

From a hypothetical American city with 1 million people, Wolman quantified the fluxes of input and output of materials, energy, water and waste (Kennedy et al, 2007). His definition of metabolic need is “all the materials and commodities needed to sustain the city’s inhabitants at home, at work and at play” (Wolman 1965,p. 179 quoted by Barles, 2010, p.441).

Since Wolman’s research, many studies have been further conducted on the subject of urban metabolism, especially quantitative analysis in diverse cities across the world. Some authors on the subject that came shortly after Wolman’s work are Eugene Odum, who described the city as a parasitic ecosystem; and Paul Duvigneaud, who gave focus to the city ecosystem (Barles, 2010).

While ecologists define the metabolism of an ecosystem as the relation of organic matter produced and consumed, Kennedy et al (2007, p. 44) define the urban metabolism concept, in a broad context, as “the sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste”.

The urban metabolism concept is extremely multidisciplinary. Although mainly within the ecology field, it is translated to industrial, urban and even territorial aspects. It is directly linked with the concepts of ecological footprint and sustainable development previously discussed in the section of *Green economy and sustainable development*. Besides, it is also connected with the linear and circular approach presented in the section of *Circular economy*. Nevertheless, such concepts tend to not focus on the role of cities as agents of material and energy flows, which is in fact considerably high. (Barles, 2010; Kennedy et al, 2007).

From the many scholars building models on the process of urban metabolism, *Figure 3* shows the evolution of the main models presented by Zhang (2013). They present as the first attempt of building a model the one from Wolman, in 1965, with a linear model of urban metabolism, including processes of input and output. Later, there is the cyclical processes proposed by Girardet, in 1990, with the use of a black box to represent the unknown components in the system. Later, there is the model proposed in 2009 by Zhang and fellows, with a network process focusing on improvement of the black box, by proposing this process as a transformation one, based on the theory of complex urban ecosystems.

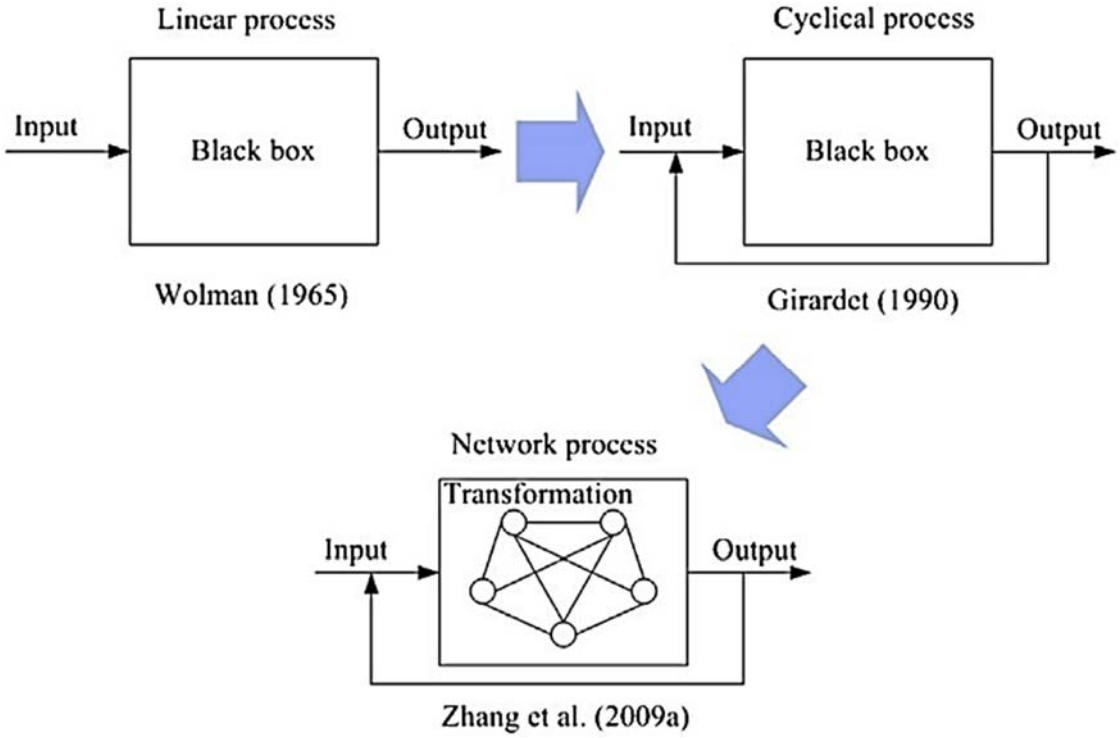

Figure 3: The evolution of models of the processes that define an urban metabolism

(Source: Zhang, 2013, p. 465)

Kennedy et al (2007) study in their paper how the urban metabolism is changing in a variety of cities. While most cities presented have had an increasing metabolism to aspects such as energy, materials, water and wastewater, the aspects of air pollutants and solid waste stream appeared to be mixed. For example, some cities that implemented recycling at the large scale and, although having reductions in waste disposal coming from residences, had an increase in the waste coming from industries and commerce.

There are many reasons why the urban metabolism concept has such a high relevance and, thus, more study about it should be carried out. One of the reasons pointed out by Kennedy et al (2007) is that an increase in the metabolism leads to even larger ecological footprint. Therefore, studying about how to decrease this urban metabolism is a valid tool to work in direction to a sustainable development. Another reason is that, especially for urban policy makers, knowing what and how they are using the city's resources, compared to other scenarios, may help developing more efficient strategies.

1.4 Strategic spatial planning

During the 1980's, planning practices in Europe tended to focus on projects and land use regulation. By the end of that century, strategic planning started to gain more attention, with the common objectives of reaching a more coherent spatial logic that gathered resource protection, land use regulation, and investments in regeneration and infrastructure (Albrechts et al., 2003).

One of the most influential urban planners with focus on strategic spatial planning, Patsy Healey (apud Friedmann et al, 2004) defends that strategic planning is extremely linked with the style of governance and the change of convictions. Further, "strategy-making is a process of deliberative paradigm change. It aims to change cultural conceptions, systems of understanding and systems of meaning. It is more than just producing collective decisions" (Healey, 1997, p.245, quoted by Friedmann et al, 2004, p.51). From her sentence, it is possible to evidence the need of a transparent process together with a strong sense of rationality, so that to build a strategic planning that attends the aims of the different stakeholders.

Something important when addressing strategic spatial planning is to understand that an efficient one should work focused on the long run development. With focus on examples from Hong Kong, China and Vancouver, Friedmann et al (2004) demonstrate that, although with different regional governance arrangements, all cases clearly show the ambition of a long view associated with their operational plans. Hence, a strategic spatial planning should be part of a long and lasting process to be taken among different actors through time. Although probably to be enhanced as all learning processes, it should maintain its core nature and objectives across time.

The strategic planning is, thus, part of a complex process involving a variety of actors. "Long-range planning studies are best conducted with extensive and informed public discussion and debate" (Friedmann et al, 2004, p. 56). It is directly linked with high levels of institutional proximity, in order to connect the different actors involved, to which the opinions and awareness of the population play important roles. The need for an institutional proximity, together with a collective learning will be discussed further in the next section, *Institutional change and collective learning.*

In line with the long range approach and high complexity of the strategic spatial planning, Healey (2004, p.61) corroborates by saying that:

> Spatial strategies achieve their effects, if they get to have any leverage over future conceptions and actions, over the long term. They do this by influencing agendas of projects and schemes for physical development, and by shaping the values with which the qualities of places are promoted and managed. Shifting such agendas and sets of values is a complex institutional project which unfolds over time and unevenly […]

It is interesting to highlight the strong connection between strategic spatial planning and strategic management. As a matter of fact, the strategic planning or strategic thinking, independently of its field of work, may be considered to have roots on the strategic management. In the business field, a very well known author that has many works dealing with strategy, among other subjects, is Michael Porter. He argues that the strategic planning field began already in the 1950s and, since then, has grown in scope and importance (Porter, 1983). When formulating an effective business strategy, Porter (1983) presents four key elements: Company strengths and weaknesses; personal values of the key implementers; economic and technical opportunities and threats; and broader societal expectations. All these elements should work according to both the internal and the external environment, in order to work in reality. When analyzed from a spatial planning point of view, the business ideas of strategic planning may be easily connected if looked from a general and wide manner, as they are related in many aspects.

Much more than the relation with the management field, the strategic planning is extremely multidisciplinary, thus requiring a multidimensional approach when dealing with a variety of issues. “In addition to the traditional social and economic dimensions, planners are now asked to integrate territorial policy agendas for environmental sustainability and cultural identity as well” (Friedmann et al, 2004, p. 52). Therefore, especially when dealing with the topic of this research, that is, the electronic waste planning, both the environmental and cultural aspects of every context analyzed are extremely important to be taken into consideration.

The term *strategic spatial planning* may cause some debate, as there is not one single and global definition on its real meaning. Nevertheless, Healey (2004, p. 46) understands the term as “self-conscious collective efforts to re-imagine a city, urban region or wider territory and to translate the result into priorities for area investment, conservation measures, strategic infrastructure investments and principles of land use

regulation". She also argues that much of the discussion focus on the process, rather than on the nature of the concepts of space and place, to which she justifies by the difficulty in addressing a technical analysis and translating the elements of the concept into programmes and policies (Healey, 2004).

Albrechts et al. (2003) discuss the raising interest in strategic planning and the main driving forces for that, by analyzing three cases. The first example presented is the Hanover city, which has raised the efficiency of strategic planning by adopting visionary and participatory approaches with regional cooperation. The second is the Flanders case, creating a regional identity by changing the dispersed development to growth management, according to sustainable development practices. The last is Northern Ireland, providing an example of the relation between the national and European planning ideas, taking into consideration the divided society in the country.

Some lessons may be taken from the case analysis from Albrechts et al. (2003). The first one is that spatial planning initiatives have many different forms, according to each context. Accordingly, it is essential to take into consideration the different scenarios when adopting a spatial planning approach. Another point is that, although this approach may bring innovation forces, it may also represent a regressive step, if spatial organizing concepts are not taken together with persuasive institutional alliances. This point is directly linked with the need of an institutional change, which will be dealt further in the next section. Besides, the development of this spatial dimension goes beyond technical analysis, to a need of develop metaphors and spatial logic. The importance of creating institutional arenas for the regional spatial development initiatives is also pointed out. The last lesson presented is that the political consciousness and place identity influence the result of such initiatives.

1.5 Institutional change and collective learning

Environmental challenges, like overconsumption and waste, represent today highly complex problems. Most of the times, there are many causal factors and other minor problems interlinked, which can make it difficult to identify the main problem and, therefore, to work focused on the solution of the main problem. When looked at a large scale, they usually result in different perceptions on what the problem is, as they are the

result of a linkage of many other minor ones. Besides, there are often many paths that can be taken to solve such problem.

Environmental challenges are not fully predictable and, very often, different approaches may result in unforeseen consequences. Especially due to the connection of these factors, there is not a clear, neither one single response that can be put into practice, representing a complex and often global system. With such a high complexity and the fast changes in the scenario, the understanding of the process should be constant, being part of a long learning process.

The importance of addressing environmental challenges is evident, as they appear as one of the most pressing challenges facing the society today. Nevertheless, as pointed out by Lintz et al. (2011, p.12 apud Hamdouch, 2015, p. 123), the literature that connects this subject with a sustainable development, especially in the urban and regional sphere, is rather limited.

Something interesting to mention is that this lack of literature may be due, among other factors, to the high complexity demanded of linkage of policies and fields of studies. Environmental issues do not belong to a single area of study, but are the result of the junction of many disciplines, like geography, biology, political science and economy. It requires, thus, a multidisciplinary approach for planning actions aiming to a more sustainable future.

> The transformation into an inclusive green economy requires the integration of environment issues into other policies, such as energy, transport, agriculture, fisheries, trade, economy and industry, research and innovation, employment, development, foreign affairs, security, education and training, as well as social and tourism policy, so as to create a coherent, joined-up approach. Action within the Union should also be complemented by enhanced global action and cooperation with neighbouring countries to tackle common challenges. (EC, 2014, p.19).

Barbier and Markandya (2012) also defend that an increasing collaboration among different fields of studies, like economists, environmental scientists and ecologists brings many positive results. Much more than desired, such a collaboration is mandatory when searching for monitoring environmental impacts. They also point out that this interdisciplinarity is what makes possible to identify the complex environmental problems that are growing in a global sphere.

Sustainable development is an approach that has been gaining strength throughout the years. According to Hamdouch and Zuindeau (2010b), already in 1987 the concept appeared in the report elaborated by the World Commission on Environment and

Development, *Our Common Future*. Since then, the approach has been developed gradually, both in terms of practical and methodological improvements.

Nevertheless, the authors argue that 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 and Zuindeau, 2010b, p. 435).

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.

In order to discuss the need for an institutional change, it is first important to fully understand the real meaning of the term *institution*. Ménard (1995, p. 167, quoted by Hamdouch, 2005, p. 232) defends that:

> An institution is manifested in a long-standing historically set of stable, abstract and impersonal rules, crystallized in traditions, customs, or laws, so as to implement and enforce patterns of behavior governing the relationships between separate social constituencies.

Independently of the institution, each one has a set of common characteristics, as pointed out by Hodgson (1998, p. 179, quoted by Hamdouch, 2005, p. 233):

> All institutions involve the interaction of agents, with crucial information feedbacks. All institutions have a number of characteristic and common conceptions and routines. Institutions sustain, and are sustained by, shared conceptions and expectations. Although they are neither immutable nor immortal, institutions have relatively durable, self-reinforcing, and persistent qualities. Institutions incorporate values, and processes of normative evaluation.

It is possible to infer from both definitions that an institution should not be dependent on personal ideas and habits but, instead, on the common goals and objectives of the ones involved in an organization, a community, a territory or in the society considered as a whole.

Ménard (1995, quoted by Hamdouch, 2005) also describes the difference of an institution to a market or organization. While institutions help to build rules (both formal and informal), markets and organizations work according to them. In this sense, by analyzing the true meaning of institutions, it is evident that they should not be in a constant state of change of principles due to the different governments in power, but rather

have long-term goals that are respected and followed by individuals, organizations and markets, throughout time, independently of each government in charge.

In the same perspective, Hamdouch and Depret (2012, p. 72) argue that "the simple combination (or integration) of policies is not sufficient in itself. It also requires a strong and lasting coordination over time of the policies that are engaged". By giving the example of bio-fuel industries in Japan, they explain how a poor coordination of policies over time can have very limited results or even fail.

One of the big challenges concerning the adoption of different institutions is to find objectives and goals that are common and interesting to all stakeholders. According to Hamdouch (2005), although there is a clear view from institutions to achieve economic coordination, the theoretical connection between this coordination and the institutions is still poor.

From the definition of institutions and the notion that they should work toward common goals, Hamdouch (2005) argues that a strictly calculated and individual rationality works in the opposite direction and, as consequence, makes the linkage and coordination of actors impossible.

To defend the argument, he works based on two propositions. The first one is that "*L'existence et la légitimité d'institutions en amont et/ou au sein de la coordination sont logiquement impossibles sous l'hypothèse de rationalité strictement individuelle et contrôlée*"[1] (Hamdouch, 2005, p.236).

In his first proposition, Hamdouch (2005) explains that a behavior based on strictly controlled and individual rationality leads to inter-individual conflict, as each individual has distinct ideas and ways of thinking. Further, this leads to not only a problem in the creation of institutions, but also in their legitimacy, considering that the collective aims will not be on focus, which is one of the basis of an institution. Therefore, the existence of institutions implies that they work in an endogenous and coordinated manner, but not intentional neither calculated one.

The second proposition presented by Hamdouch (2005, p. 240) is that "*Sous l'hypothèse de rationalité strictement individuelle et contrôlée, il n'existe logiquement*

[1] Authors' translation: The existence and legitimacy of institutions upstream or within coordination are logically impossible under the hypothesis of a strictly controlled and individual rationality.

aucune procédure collective garantissant l'élaboration et la légitimation de règles ou de dispositifs spécifiques de coordination"[2].

With the second preposition, Hamdouch (2005) argues that this impossibility is directly linked with the first proposition. He affirms that the behavior of agents within an institutional setting should be based both on the principle of a socialized rationality and of a systemic rationality.

The socialized rationality means that the term *rationality* should no longer be perceived as an individual property, but as an interpersonal one, as the perceptions of different agents affect each one's perception. The systemic rationality represents the interdependence of agents in the context and through time, considering the interactions and preferences of the individuals and the group. By adopting this social and systemic rationality principle, it would be possible to have an endogenous emergence process of institutional settings that will frame workable the rules and devices necessary for coordination, while ensuring the legitimacy and effectiveness of the institutions to which individuals and organizations comply (Hamdouch, 2005).

Turning now specifically to the required shift for a more sustainable development model, today it is widely recognized that there is a huge "combined search for social equity, environmental protection and economic efficiency, to which should be added the objective of governance" (Hamdouch and Zuindeau, 2010b, p. 429). The authors justify that there is a growing need for innovative methods and approaches, since the traditional ones have very limited perspectives concerning policies and practices that must be improved.

Hamdouch and Zuindeau (2010b) point out to three characteristics that indicate that new methods and approaches must be put into practice for obtaining a sustainable development model, as they do not usually work in a systematic way. The first one is that sustainable development is multi-dimensional, with a broad range of objectives that involve several and different fields of work. The second characteristic concerns the governance dimension, as its high importance "calls for a greater democratization of the processes in question, mobilizing stakeholders [...] as much as possible and offering them opportunities for 'empowerment' and for expressing their expectations" (Hamdouch and

[2] Authors' translation: Under the hypothesis of a strictly individual and controlled rationality, there is no collective logical procedure to ensure the development and legitimization of rules or specific coordination mechanisms.

Zuindeau, 2010b, p. 430). Lastly, the third characteristic is the increasing uncertainties and risks that the world faces and the goal that sustainable development has to integrate them, especially those that lead to non-reversible consequences.

These three characteristics underlie a major change in the way actors think and behave together for a new model of development. Hence, they imply that a certain *cognitive alignment* among stakeholders can sustain the needed institutional change. It is here that *institutional proximity* can play a crucial role in favoring planning and policy-making processes based on sustainable development principles. Finally, they point to the necessity to have an *integrated and time-coherent approach* to regulations and policies that can contribute to the adoption of a more sustainable development model instead of isolated measures or provisions.

By a matter of fact, the European Commission recognizes the importance of having an institutional proximity among actors and more integrated approaches to work in direction to a sustainable growth model. According to EC COM 21 (2011, p.8):

> […] the fact that resource efficiency requires action in such a broad range of areas means that modelling is particularly complex. Existing models focus on specific policy areas and sectors such as energy and transport. They cannot capture fully the impact of resource use on ecosystems, enterprises, the economy and society as a whole, or the interdependence of policy measures.

As stated in the Europe 2020's website concerning the flagship initiatives, it is necessary to ensure more than the engagement from the European Commission, but also from trade unions, business, NGOs, consumer organizations and academics, all together, for the circular economy system to be put into practice. It is also stated that the evaluation of policies and the collection of life-cycle data is needed to develop policies, besides more harmonized ways of measuring environmental impacts.

Concerning the difficulty for planners to work with approaches and actions for a sustainable development, Hamdouch (2015, p.123) affirms that:

> […] la principale difficulté à transposer le développement durable et ses outils [...] réside, à notre avis, dans l'inertie plus structurelle qui caractérise encore les visions et les pratiques des responsables politiques et des aménageurs.[3]

From this statement, the author complement by stating that this inertial behavior may be due to several factors, like strong cultural roots in old models, lack of knowledge

[3] Authors' translation: […] the main difficulty in transposing sustainable development and its tools [...] resides, in our opinion, in the structural inertia that still characterizes the visions and practices of politicians and planners in charge.

(especially on the local level about environmental issues), or lack of interest for political reasons. Therefore, the main goal for planners when conceiving sustainable urban plans is to gather sustainable development goals, both at the social and the environmental level, with their economic goals, without forgetting to consider the cultural acceptance and limitations of each reality.

Hamdouch and Zuindeau (2010a) further discuss the subject of sustainable development, by defending that it amplifies the understanding and boosts the deployment of new practices, especially at the territorial and socio-institutional level.

Concerning the territorial axis, the concept represents much more than the space itself; it is the social result of the union of different characteristics, such as sociocultural, institutional and historical, that may converge to a certain extent and contribute to disseminate sustainable development principles and convert them into actions within a given territory. As such, the territorial axis may have different levels of importance in the strategy for sustainability, depending on the prevailing territorial context and its *permeability* for change and the adoption of new approaches, technologies and *ways of doing things* (Hamdouch and Zuindeau, 2010a).

The socio-institutional axis has a very high impact on sustainable development and is, at the same time, extremely diverse. It appears in different dimensions, of which the authors quote the three most relevant ones. The first is that it may appear in different territorial levels, like countries, regions, cities or neighborhoods, which will result in different configurations, according to policies in practice. The second one is that it involves a vast array of actors, from government to citizens. Lastly, it depends on innovative approaches for facilitating the interaction among actors and contributing to the emergence of shared visions and aims (Hamdouch and Zuindeau, 2010a).

More specifically, Hamdouch and Depret (2012, p.72) explain why there are diverse factors that impact the development of environmental innovations processes according to different sectors, types of technology, period of time and, especially, territorial space:

> The long-term and territorial co-integration of public policies is to a great extent contingent in nature. This is especially due to the various uncertainty sources that may affect each of the policies' effectiveness. Institutional factors that shape consumers and investors' behaviour, as well as many demand and supply factors (economic financial, scientific, technological, social, etc.) are susceptible to weaken policies' expected effects. Not only do these various factors combine (Grubb, 2004; Kivimaa, 2007), but also, and more fundamentally, they induce one another and

> therefore co-evolve alongside each other within a time-space dynamics that is specific to a certain territorial setting [...].

Despite these real difficulties in adopting a systemic planning and policy approach, Hamdouch (2015) defends the idea that it is possible to obtain a sustainable territorial development in different socio-economic contexts and territorial scales, especially when dealing with green activities. Moreover, it is on the metropolitan/urban scale that strategies toward a sustainable development should be primarily addressed, since there is a huge and growing concern towards sustainable urban approaches.

In order for countries or regions to develop a *green economy*, Hamdouch and Depret (2012) and Depret and Hamdouch (2013) stress a series of common characteristics that were 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.

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 may have strong impacts in the economy, increasing its growth and changing models of competition.

There is an extreme importance in 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 of 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.

Indeed, special attention is given from the European Commission to the improvement of cooperation among different actors for the implementation of a circular economy model:

> Transition to a more circular economy requires changes throughout value chains, from product design to new business and market models, from new ways of turning waste into a resource to new modes of consumer behaviour (EC COM 398, 2014, p. 2).

The report also states that a change in the whole system is mandatory, as well as innovation in technologies, methods, organizations, policies and society.

Equally important is the implementation of new negotiation and participation approaches. Hamdouch (2005, 2015) argues that, when planning for a sustainable urban development, approaches should be based on democratic pillars of negotiation. Such approaches involve the needs and aims of the different stakeholders and, thus, will have more chances to be effective and successful.

Finally, Hamdouch and Depret (2012, p. 50) make an interesting comment in relation to technology and the need for more environmental-oriented policies:

> Although many consider "technology" to be one of the main causes of climate change and environmental degradation, along with demographic change and economic growth, it also represents a key solution. More "sustainable" technologies, products, services and processes will become available, to a certain extent, over the short to mid-term and can therefore be deployed rapidly if suitable public policies are put in place.

These conditions, policy perspectives and socio-economic opportunities appear critical in shaping the change towards a more sustainable development approach.

Following this line, the Roadmap to a Resource Efficient Europe points out to a combination of policies that could help working to achieve a full recycling economy, like "product design integrating a life-cycle approach, better cooperation along all market actors along the value chain, better collection processes, appropriate regulatory framework, incentives for waste prevention and recycling" (EC COM 571, 2011, p. 8). High quality recycling and public investments in modern facilities for waste treatment are also pointed out.

The collection infrastructure for waste, especially for Waste Electrical and Electronic Equipment, has proven to be ineffective in many countries, which is due, in a vast proportion, to the lack of harmony among different actors in the value chain. On the other hand, the Swedish case, as it is discussed in the part of the case studies, represents a good example of a system with a high level of institutional proximity.

Hamdouch (2015) studies the main urban transformations in the specific case of Stockholm. The city started to worry about environmental issues back in the 1990's and, especially for the next 10 years from then, a series of environmental policies started to be

put into practice. One of them is the new environmental code, adopted in the beginning of 1999, which aimed at a better environmental protection and climate change control.

Also by the middle of 1990, a wide urban transformation programme started in Stockholm, which is supposed to continue until the 2030's and is reshaping the urban model under a sustainable view, according to the cultural, economic and residential areas. At the same time that it will make the urban areas more densely populated, the project aims at connecting the different modes of transportation, both public and private, besides promoting new neighborhoods close to the historical center. Another huge project is the *Norra Djurgårdsstaden*, with the objective of transforming the old industrial and harbor area into a sustainable urban neighborhood by 2025, offering new housings and jobs. A new sustainable development plan was adopted in 2007, the *Vision Stockholm 2030* and, by 2009, a new global plan, the *Stockholm City Plan*, updated the previous version (Hamdouch, 2015).

It is interesting to comment that a city that wants to change its planning model to a more sustainable one and, at the same time, to promote its economic strength, especially in the innovative and technological field, while offering a high quality of life, faces a very complex and difficult change. When considering the economic and social constraints, besides the environmental issues present at the time (Hamdouch, 2015), such changes seem to be even more difficult. Nevertheless, Stockholm has made use of high investments in urban and suburban infrastructure, together with a serious commitment of different parts involved, in order to effectively reshape the city into a more sustainable one:

> Depuis plusieurs décennies, la municipalité de Stockholm (grâce notamment aux compétences et à la légitimité reconnue de son agence de l'urbanisme et de l'environnement) a ainsi initié et coordonné tous les grands projets d'infrastructures urbaines, de construction de logements collectifs, d'impulsion et de mise en oeuvre d'une politique culturelle très dynamique, d'équipements en matière d'éducation et de loisirs, et, depuis les vingt dernières années, en matière d'environnement, de recherche et d'innovation dans une stratégie intégrée d'attractivité et de compétitivité économique, en même temps que les objectifs d'intégration des populations, de cohésion sociale et de qualité de vie ont été constamment réaffirmés[4] (Hamdouch, 2015, p.132).

[4] Authors' translation: For several decades, the municipality of Stockholm (thanks notably to the skills and the recognized legitimacy of its environment and urban planning agency) has initiated and coordinated all major projects of urban infrastructure, collective housing construction, and implemented a very dynamic cultural policy, facilities for education and recreation and, for the past two decades, of environment, research and innovation as an integrated strategy of attractiveness and economic competitiveness, at the same time that the objectives of population integration, social cohesion and quality of life were constantly reaffirmed.

Stockholm has made serious improvements in the environment, like with the decrease of greenhouse gas emissions, as well as in the technological and economic side, with the development of a series of high-tech dynamic clusters. Further, it has a high level of educated population and is constantly ranked among the top in indexes such as of economic growth and competitiveness (Hamdouch, 2015).

The case of Stockholm shows how the commitment of planners and public actors in engaging the private actors and the population, by using a participative and collective approach together with long-term planning, made the implementation of sustainable urban transformation projects possible. In the next session, the specific case of the management of Waste Electrical and Electronic Equipment in Sweden is studied, as means to identify if such approach also applies to this particular case.

2 THE EUROPEAN SCENARIO

2.1 The European Commission programmes toward 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 Waste of Electrical and Electronic Equipment.

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, and this 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 analyzing 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 will 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 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 maximise 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 Waste Electrical and Electronic Equipment, 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. 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% by 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 under 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 making the circular model appear 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 4*.

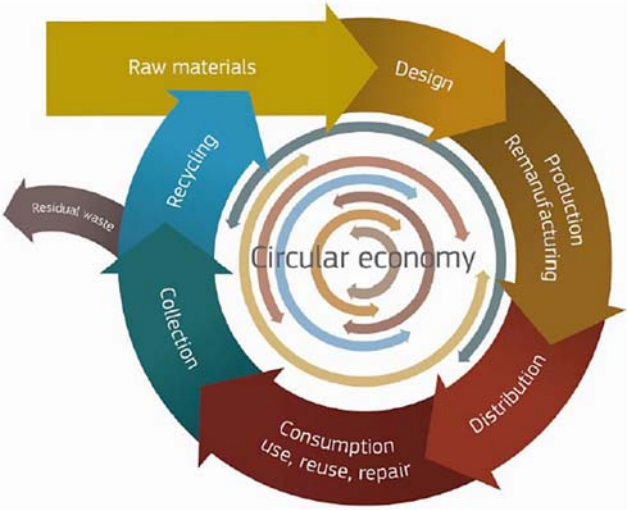

Figure 4: Main phases of a circular economy model

(Source: EC 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 may 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 Waste Electrical and Electronic Equipment, 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 environmental-friendly and economically efficient model for production and consumption processes, and specifically by facing waste management problems along the whole value chain. However, as this has already been suggested several times in section *1.5 - Institutional change and collective learning*, 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.

2.2 The situation towards electronic waste in Europe

As it has been possible to see in the previous sections 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 *Figure 5*, 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.

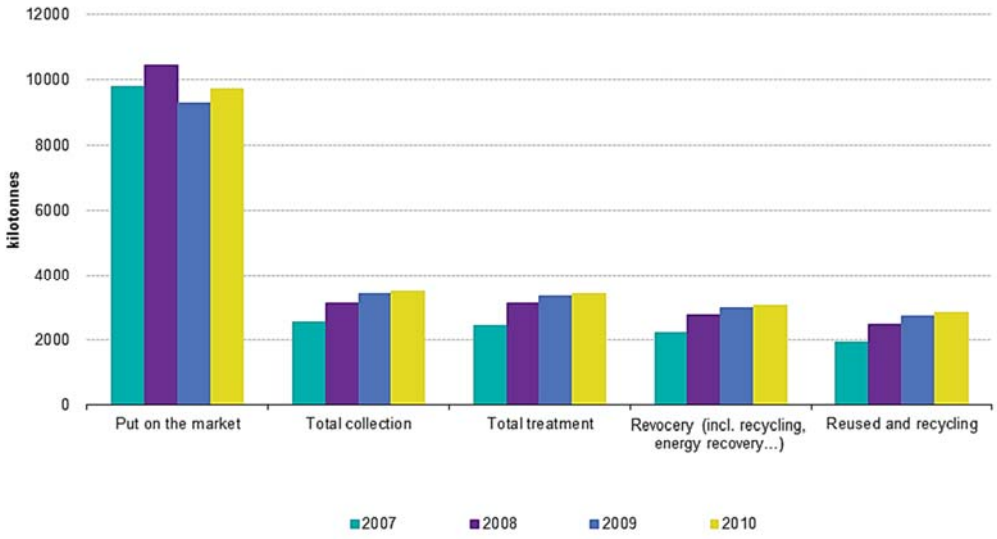

Figure 5: EEE put on the market and WEEE collected in the EEA

(Source: Eurostat, 2013)

Concerning the scenario in every country, *Figure 6* 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 this goal and, as it is possible to identify in *Figure 6*, 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. The collection rate of the French system is 6.9 kg per capita.

According to The World Bank Project Report (2012), Europe represents an example of pioneer achievement in semi-precious processing in large scale. There are only four large companies today processing precious metals worldwide in an environmentally friendly way, of which three of them are in Europe, one being in Sweden.

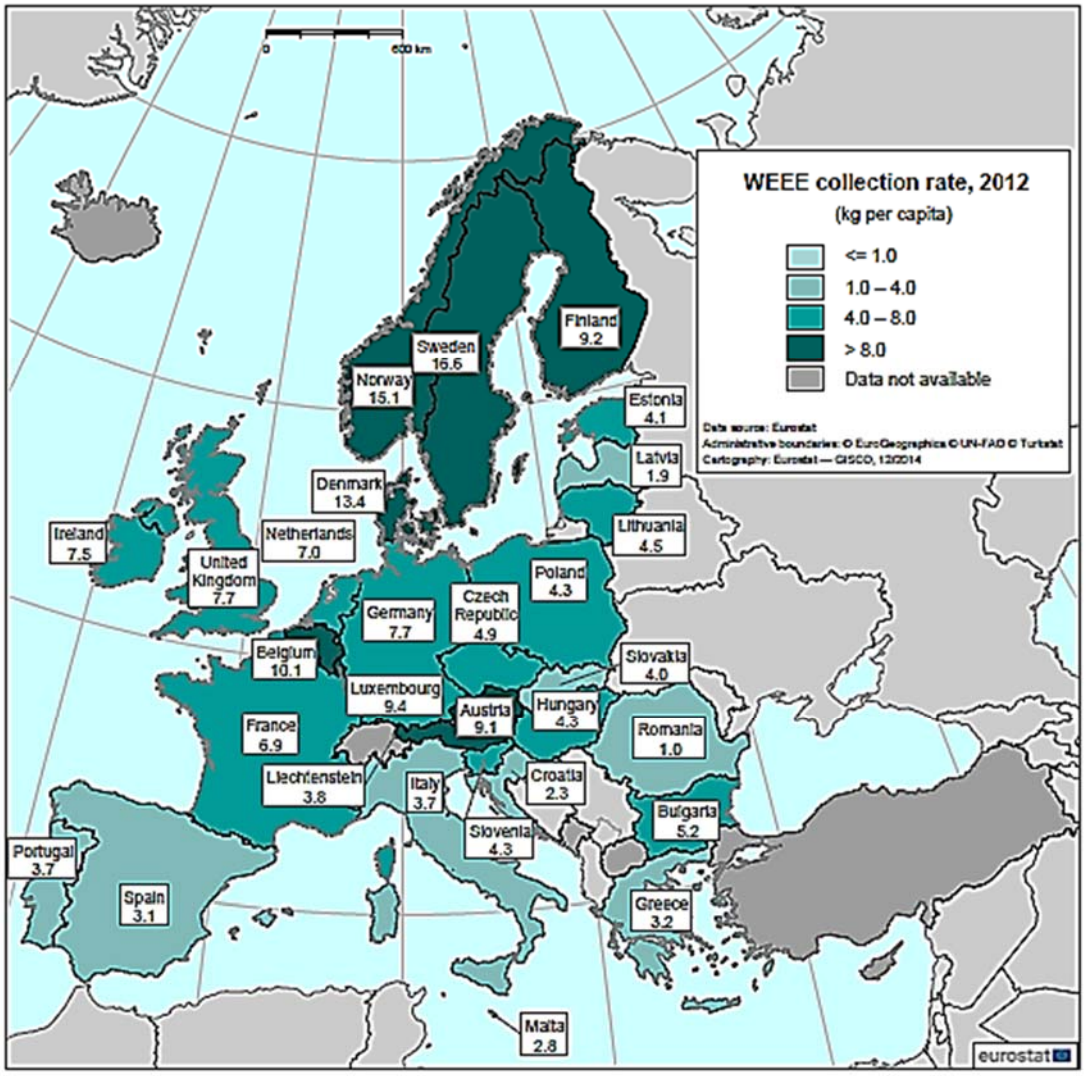

Figure 6: Waste Electrical and Electronic Equipment collection rates in 2012

(Source: Eurostat, 2012)

Sweden represents the best example within the European Economic Area not only in absolute collection rates. When analyzing 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, *Figure 7* 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.

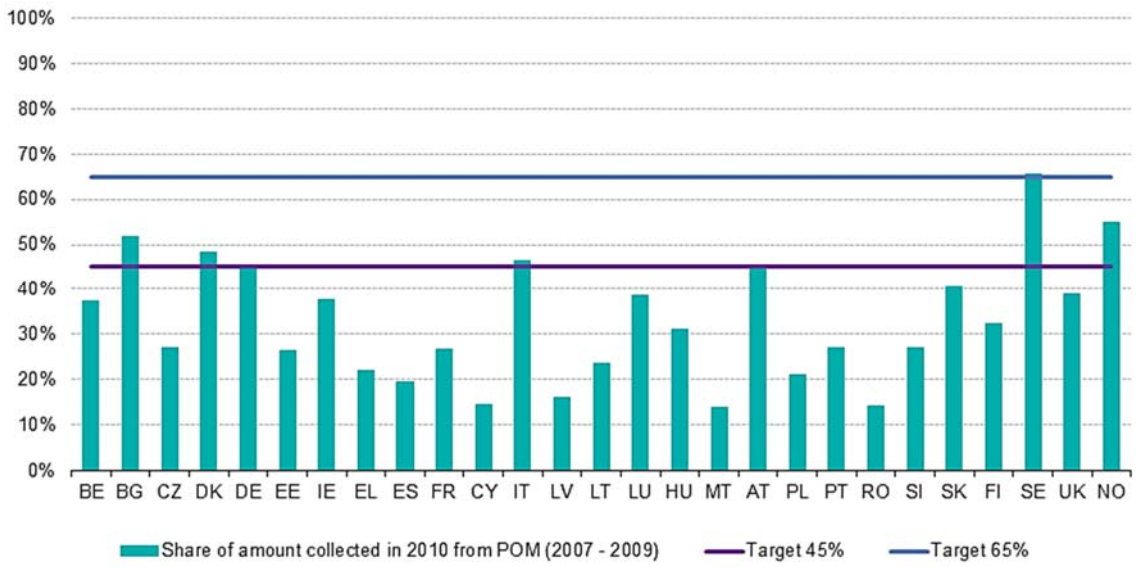

Figure 7: Collection rate for WEEE in 2010 as a percentage of the average weight of EEE put on the market in the three preceding years in the EEA countries

(Source: Eurostat, 2013)

2.3 The European legislations toward 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 play 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 that should be applied by all European Member States.

The first Waste Electrical and Electronic Equipment (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 to collect the Waste Electrical and Electronic Equipment free of charge from the consumers.

According to The World Bank Project Report (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 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, RoHS Directive 2002/95/EC, 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).

3 FINAL CONSIDERATIONS OF PART I

Part I has had the main aim of introducing the main concepts related to the topic of research, as a way of building a foundation for a proper understanding of the case studies in *Part II*. It has brought a variety of different concepts, as result of the high complexity in which the recycling of electronic waste is involved.

Firstly, it has presented a literature review about subjects that, although different, 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 spheres, 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 recycling of electronics.

By the common understanding that the management of waste, no mattering which kind, is a fundamental part of the city's planning aspect, the subject of electronic waste management is directly linked with the planning field. In this sense, it has been studied further in the literature about urban metabolism, as a way of facilitating the flow analysis of both energy and materials in a specific place, by providing a framework to understand the technical and socio-economic processes occurring in such a place. The strategic spatial planning concept has also been studied, which requires a multidimensional and usually joint approach, focusing on the long run in order to succeed.

It is important to mention that all concepts already mentioned in the literature review, although may seem simple, involve a whole change of mentality and approaches, making its implementation rather complex. It is not only the result of a collective approach, but also of a collective learning process, as it evolves through time, working on the long run. In this sense, it is also highlighted the concept of an institutional change and a collective learning, by gathering the different actors involved and closely working to achieve common goals.

Besides the literature review, the European scenario has also been studied in *Part I.* 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 on 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 of e-waste when compared to other countries. From the collection rates analyzed, 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 also 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.

PART II

INSTITUTIONAL SETTINGS TOWARD THE MANAGEMENT OF WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT: FOUNDATIONS AND LESSONS FROM THE SWEDISH, FRENCH AND BRAZILIAN CASE

In *Part II*, it will be analyzed how Waste Electrical and Electronic Equipment is managed and treated in different countries. The main goal is to bring insights for future planning approaches dealing with this specific kind of waste, which demands a very different treatment from the regular waste and is involved in a highly complex system.

The first section of *Part II* explains why Sweden, France and Brazil have been chosen as case studies. It clarifies the main and specific objectives of the research, as well as present the research methodology for the case studies.

Considering that, as presented in *Figure 6* and *Figure 7*, Sweden is considered to have the best recovery system from the material efficiency point of view and is notably known as one of the most environmentally friendly countries in the word, the Swedish system will be studied first. It is assumed that, in order to have such a highly efficiency, Sweden has some positive aspects in its planning and management that may serve as an example for other countries.

Secondly, it will be studied how the process is done in France. Lastly, an analysis of the Brazilian system will be made. By comparing such different countries, it will be possible to have a broad idea of some of the different approaches in practice, always taking into consideration the different scenarios and realities of each environment.

Appendices B to F bring some general information about each country profile that will be studied further in the case studies. The appendices show data about the geography, demographics, government, economy and telecommunications, respectively, for Sweden, France and Brazil.

4 THE CASE STUDIES

4.1 Selection of the case studies

After reviewing the literature and studying the European scenario in *Part I*, it has been possible to draw some conclusion about the subject to be studied and, from this, to develop a proper research methodology for the case studies.

As pointed out in section *2.2 - The situation towards electronic waste in Europe*, Sweden has the best recovery system of Waste Electrical and Electronic Equipment from the material efficiency point of view in the European Scenario. Taking this into consideration, the first country chosen to be studied further is Sweden, as means to identify the key elements that make this country having such a highly efficient system, as well as drawing some lessons and examples that may be applied to other countries and future planning systems.

The second case study will be the French one. Within the European scenario, the country is under the WEEE and RoHS Directives, pointed out in section *2.3 – The European legislations toward electronic waste,* just as the Swedish case. Nevertheless, as many other European countries, France has a much lower collection rate of electronic waste per capita than the Scandinavian countries with data available. Thus, it is believed that an analysis of these two scenarios in Europe - Sweden and France - may bring some interesting insights for the future of e-waste planning in Europe.

The last case study will be from Brazil. In the scenario of the developing 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 Project Report, 2012). Therefore, the Brazilian scenario has been chosen as an interesting case to be studied further, not only among the emergent countries, but also in the global sphere.

4.2 Objectives

Part II has its own objective, with specific objectives directed to the case studies.

4.2.1 Main objective

To promote a study about the urban planning approaches toward the electronic waste management in Sweden, France and Brazil.

4.2.2 Specific objectives

1. To analyze the current actions;
2. To identify key problems in the process;
3. To compare the scenario in the three countries;
4. To propose possible actions for improvement.

4.3 Research methodology for the case studies

All the case studies analysis are based on secondary data. Each case study is presented in one chapter, in the following order: Sweden, France and Brazil. For each country, specific aspects are looked at, as a way of making the best comparison possible among the three countries.

Firstly, the relation between ecological footprint and biocapacity is analyzed for each country, from data taken from the *Global Footprint Network*. The main goal of this data is to introduce each case study to the environmental scenario, considering that the ecological footprint is one of the main environmental sustainability indicators used around the world nowadays.

Secondly, an overview of information related to electronic waste for each country is given, taken from the *E-waste World Map*. This is the first global map of electronic waste and has been launched from the STEP initiative, a partnership between the UN, different companies, philanthropic organizations and diverse governments. This data makes it possible to have a broad idea of the electronic waste scenario for the country studied.

The next section deals with how the management of the electronic waste happens on the specific country. This section comprehends data gathered mainly from reports,

laws and other public information sources available online about the planning approaches for electronic waste.

The identification of the main actors involved in each case study analyzed is done next. Such identification is the result of an analysis from the data gathered in the previous section of the country's management of Waste Electrical and Electronic Equipment, looked from a planning perspective.

Lastly, some final considerations are drawn from each case study. As means to have a better understanding of the overall scenario, a table is built with specific subjects analyzed from the specific country. After the analysis of each country separately, the final chapter of *Part II* brings a comparative analysis among all the countries studied.

5 THE SWEDISH CASE

5.1 Swedish ecological footprint

Figure 8 shows the ecological footprint of Sweden, compared to its biocapacity, from 1961 to 2011. It is possible to identify that, although Sweden has a large ecological footprint, it also has an even higher level of biocapacity, making its situation a positive one in terms of human demand on the Earth's ecosystems.

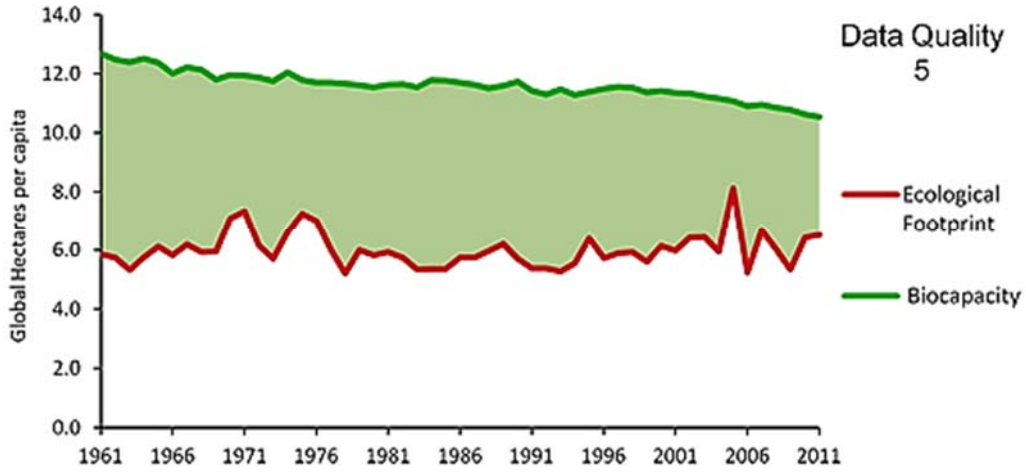

Figure 8: Ecological footprint X biocapacity in Sweden

(Source: Global Footprint Network, 2015)

In the case of Sweden, the biocapacity exceeds consumption demands. Besides, the country is among the few nations where the level of biocapacity in relation to its ecological footprint has changed in a small scale throughout the years, while at the same time maintaining the biocapacity level higher than the ecological footprint.

5.2 Electronic waste scenario in Sweden

Figure 9 has been taken from the *E-waste World Map* and shows the case of electronic waste in Sweden. It is easily observed that Sweden is not a densely populated

country, with only 9.48 million inhabitants in 2012. On the other hand, the Swedish purchasing power is the highest when compared to the other two cases that will be analyzed further. Consequently, there are more electronics put into the market per inhabitant than in the other countries, although the total amount is far less, which can be implied is due to the scarce population. The same applies to the electronic waste generated, which was 24.86 kg per inhabitant in 2012, while the total was 235.70 kilotonnes.

Sweden

Overview of e-waste related information

Subject	Unit	Year	Amount	Source
Population	(total inhabitants in million)	2012	9.48	IMF WEO
Purchasing Power*	(USD per Inhabitant)	2012	41,749.58	IMF WEO
EEE Put on Market*	(kg per inhabitant)	2012	28.70	UNU (Jaco Huisman)*
	(total in metric kg tonnes)	2012	272.05	UNU (Jaco Huisman)*
E-waste Generated*	(kg per inhabitant)	2012	24.86	UNU (Jaco Huisman)*
	(total in metric kg tonnes)	2012	235.70	UNU (Jaco Huisman)*

Figure 9: Overview of e-waste related information in Sweden
(Source: STEP, 2015)

5.3 Swedish management of electronic waste

The Swedish legislation for electronic waste works under the WEEE Directive and RoHs Directive, as presented in section *2.3 - The European legislations toward electronic waste*. The Ordinance (2005:209) on Producer Responsibility for Electrical and Electronic Equipment, adopted in 2005, transposes the European law to the Swedish scenario. The Swedish Environmental Protection Agency, together with the municipal board, is responsible for inspecting the accordance with the Environmental Code, while each municipal board organizes its systems of collection locally (EPA, 2012). “The Swedish EPA, as the authority, is responsible for reporting to the EU commission on the WEEE directives” (Lee and Sundin, 2012, p.2).

According to Ylä-Mella et al (2014), in the late 1990's Sweden already started to prepare national legislations to deal with Waste Electrical and Electronic Equipment management to control its disposal and environmental problems. Concerning the management of electronic waste, because "recycling is regarded as a solution to substitute primary resources and decrease environmental loading, the efficient recovery of valuable materials from waste electronics is indispensable to ensure sustainable materials management" (Ylä-Mella et al, 2014, p.2). In order for this to be achieved, not only a consumer awareness is mandatory, but also an adequate collection infrastructure.

The Avfall Sverige, founded in 1947, is the Swedish waste management and recycling association. It is composed by both public and private sectors, which are involved with waste management and recycling. The association has a vision of *zero waste* and works in combination with the country's municipalities and companies, in order to obtain a waste minimization and reuse (Avfall Sverige, n.d.).

According to the Elretur Report (n.d.), the producer responsibility for Waste Electrical and Electronic Equipment was introduced in Sweden in 2001. Since then, Sweden is considered as the world leader in electric and electronic waste collection. Ylä-Mella et al (2014, p.10) affirm that the main aspect of the Swedish system is "the efficiency of materials flows through centralized recycling operations and optimized transportation". The system called *Elretur* is the only nationwide collection system in Sweden and is runned by El-Kretsen.

El-Kretsen is considered to have the most efficient nationwide recycling system in the world. According to El-Kretsen's website, it is a not-for-profit service company owned by 20 business associations and is responsible for the collection and recycling of e-waste in Sweden. Companies that import or produce electronic products or batteries in Sweden are El-Kretsen's members and pay environmental charges, according to their sales. El-Kretsen's members do not need to have a system to become affiliated, so that it is possible for companies to find a cost-efficient and practical solution for the Waste Electrical and Electronic Equipment disposal, according to the legal requirements.

According to El-Kretsen Annual report (2013), almost 74 million electrical products were recycled in 2013, with a total of 146,919 tonnes of electrical waste, batteries and bulbs, or the equivalent to a 15.31 kilo per person, far from the 4 kg established by the EU Directive. Although the quantity of collection itself was higher on

2013 if compared to 2012, the weight of collection was lower, which may be explained by the electronic products becoming lighter.

The Swedish law states that local authorities of all the 290 municipalities should manage their household waste (EPA, 2009). The collection system has localized implementation and cooperation with the Swedish local authorities, meaning that:

> […] the local authorities manage and fund manned collection points, such as recycling centers, where the households may leave the WEEE without charge. El-Kretsen manages and funds transports of the WEEE to pretreatment and recycling in accordance with the prevailing laws (Elretur Report, n.d., p.2).

The electronic waste is collected by both municipalities and businesses and, after, transported to specialized recycling facilities that are connected to El-Kretsen. The Swedish legislation regulates the pretreatment of material with developed standards and a code of conduct, by settling agreements between El-Kretsen and the recycling companies.

Further, all facilities are audited and should report to El-Kretsen and supervisory authorities periodically, including:

> […] for how the WEEE have been treated, where to the fractionated material, such as metals, plastic, and hazardous waste, has been sent, and how this material has been treated at the receiving facility (Elretur Report, n.d., p.2).

Sweden has signed the Basel Convention and cannot export hazardous waste to developing countries. In exception from a small quantity exported for treatment in Norway, all other Waste Electrical and Electronic Equipment collected by the nationwide system is recycled within the country. The Swedish Waste Management Report (2013) from Avfall Sverige affirms that some used electronics are donated as charity to other countries. Nevertheless, this is not considered as the most environmentally friendly practice, since the recycling process in such countries faces many difficulties and is usually not done in a proper manner.

The collection of e-waste is handled by municipal collection points, mostly by recycling stations, which are usually the same collection points as regular waste. This gives El-Kretsen's producers access to a nationwide system. In order to introduce different methods, such as a new collection system, producers need to have local authorities' approval, in such a way that the process is always connected to the municipal waste management (Elretur Report, n.d.).

Each municipality is able to make its own decisions to how the waste collection system is organized. This flexibility allows a better approach according to each case, depending on factors such as “size of population, geographic size, types of housing, types of business and operation” (EPA, 2009, p.3).

According to the Elretur Report (n.d.), Elretur has about 1000 collection points around Sweden and is the main way of collecting Waste Electrical and Electronic Equipment. Some other ways to complement the collection process is by different types of curbside or by bulky waste rooms available in stores and companies. Avfall Sverige and El-Kretsen also develop some projects to search for new collection systems. One of these projects is called *The Collector*, special device for collection of small electronic equipment that is placed in stores, giving the population an easy and safe way of disposing their electronic waste.

The Swedish association of recycling electronic products (EÅF), launched in 2008, uses its members’ shops as collection points where possible. By an agreement with El-Kretsen, both associations work together to achieve an effective system (EPA, 2009). According to Lee and Sundin (2012), this is an alternative to the El-Kretsen system and EÅF has to pay El-Kretsen a fee, since not all local municipalities have retail shops.

The transportation from the collection point to the recycling facilities is done by El-Kretsen and the amount of waste collected needs to be reported into El-Kretsen’s web based information system, in order to plan and transport the waste effectively. Specialized loading carriers with large vehicles are used and marked with bar codes, giving information about quantities of waste from each collection point.

The transportation is different depending on each category of the Waste Electrical and Electronic Equipment: white goods; refrigerators and freezers; lamps; batteries; or various electronics. For large goods, there are individual packages and for small or middle-sized ones there are wire mesh cages for transportation. When the collection happens, empty cages replace the filled ones. The cage’s size may vary depending especially on the inflow and on the size of the collection point, making the process of loading and unloading more effective. Following, the electronic waste is transported to one of the 20 recycling plants with which El-Kretsen has an agreement (Elretur Report, n.d.).

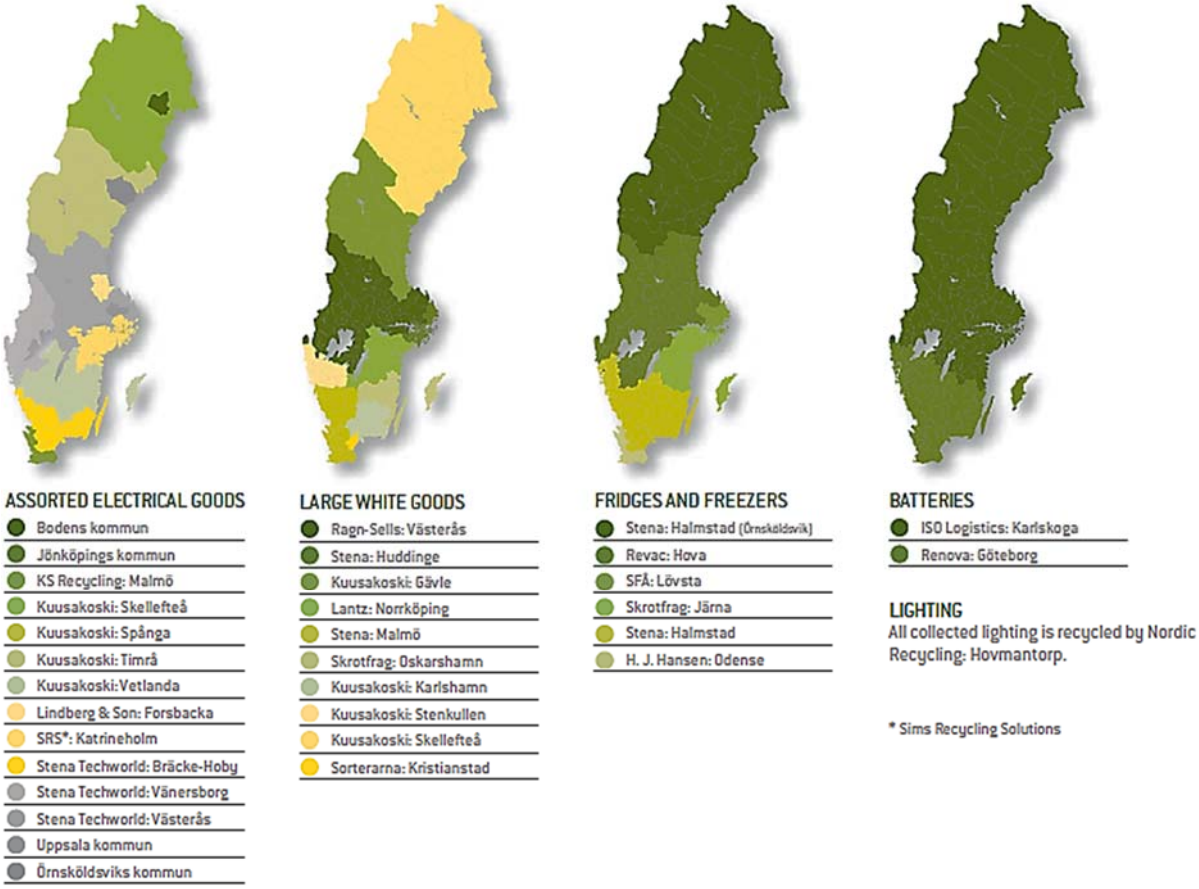

Figure 10: Catchment areas in Sweden in 2013

(Source: El-Kretsen Annual report, 2013)

By observing *Figure 10*, it is possible to understand some of the complexity in the process. The image shows the different partners responsible for each part of the country's treatment and for different categories of Waste Electrical and Electronic Equipment.

When arriving at the recycling facilities, a pretreatment of the e-waste is carried out. In order to separate the hazardous components, the dismantling of components is made, which can happen manually or automatically, depending on the product. The material that cannot be recycled, particularly some plastic materials, wood and textile, is incinerated with energy recovery, producing electricity and district heating. The material that can be recycled, such as glass, metals, circuit cards and some plastics, is recovered to be used as raw material, closing the loop towards a circular economy (El-Kretsen Annual report, 2013).

Each separated material is sent to specialized recycling companies, depending on its product category and the collection region in Sweden. “Depending on the segments, El-Kretsen has split Sweden into 1 to 14 different collection areas of various service providers based on volume, logistics costs, and location of preprocessing” (Ylä-Mella et al, 2014, p.10).

Municipalities handle the raise awareness of population. They inform households about the importance of separating the Waste Electrical and Electronic Equipment from regular waste and about the collection points. The municipality also gives the population a feedback about collection and recycling results, information that comes primarily from the producers (Elretur Report, n.d.).

According to the Sweden’s Waste Plan 2012–2017 (EPA, 2012), although the recycling Swedish system of electronic waste is very advanced, there is the potential to increase it further, especially when it comes to small devices. One major factor for that is the proper design of products, which may reduce the environmental impact with a lower amount of waste produced by society. Further, “in order to reduce the environmental impact of electrical waste, products that are placed on the market must be durable, energy-efficient and free from hazardous substances” (EPA, 2012, p. 79).

It is important to mention that even the world leader in electric and electronic waste collection system does not have an optimal system. Although the system Elretur is considered of excellence, there is still some Waste Electrical and Electronic Equipment falling outside the system , with no knowledge of whether its treatment is environmentally safe (Elretur Report, n.d.). According to EPA (2012), usually the e-waste not collected within the legal framework ends up going to developing countries, where they usually do not have an effective system for the recycling process, which causes health-related and environmental problems.

Furthermore, some electronic waste is discarded erroneously like regular waste, not having a proper disposal. According to EPA (2012), the Swedish Waste Management estimated that almost 12,000 tonnes of e-waste in Sweden ended up in the wrong place in 2008. Another point is that the population very often stores the devices after end-of-life, which interrupts the cycle for closing the sustainable loop.

Another key issue, according to Ylä-Mella et al (2014) is the long transportation distances, which brings challenges to an effective recovery system. On the other hand, as

El-Kretsen has the control over the whole recovery chain of Waste Electrical and Electronic Equipment, it is possible to establish a cost-effective system and an optimized transportation.

Lastly, Lee and Sundin (2012) present the data issue as another barrier for consumers not bringing their e-waste to the collection points, afraid of data leaking. Therefore, a surveillance system with additional screening and extra precautions should be in place, which would increase the cost of operations.

5.4 Identification of the main actors involved in the Swedish case

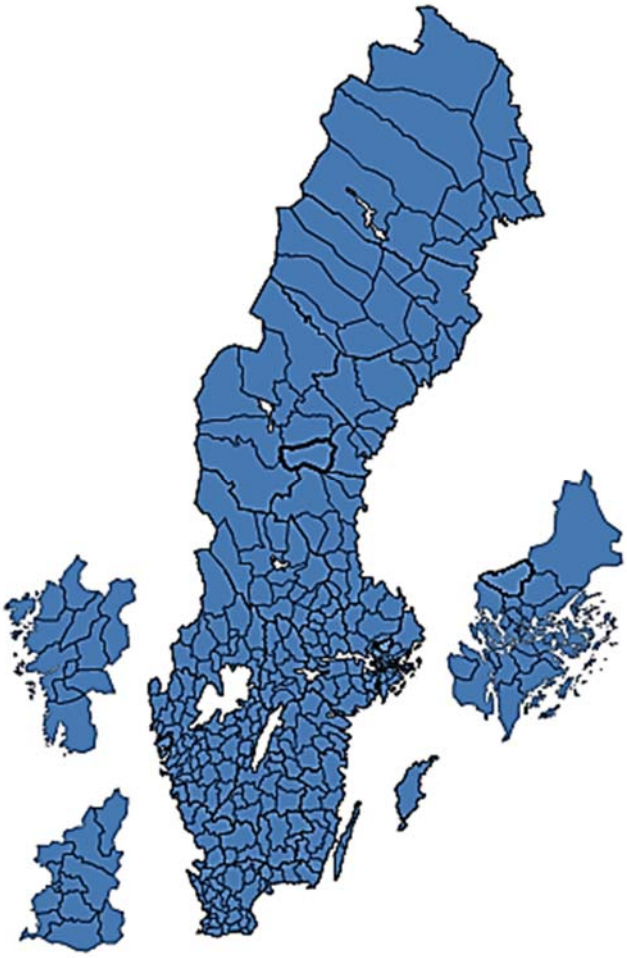

Figure 11: Municipalities in Sweden

(Adapted from: SCB, n.d.)

The planning and management of e-waste in Sweden has a national approach. Nevertheless, as already mentioned, it also depends on the municipalities, as each one of them organizes its systems of collection locally and is responsible for raising awareness of population on the subject. According to SCB (n.d.), Sweden has 290 municipalities, as it can be seen in *Figure 11*.

Besides the municipalities, that have extremely important roles to make the Swedish system works, evidently that other actors are also involved in the process. With the case study, it has been possible to identify some of the main actors involved, which were: Swedish EPA - the Swedish Environmental Protection Agency; Avfall Sverige - the Swedish waste management and recycling association; and El-Kretsen - the nationwide recycling system for collection and recycling of electrical and electronic products. More information about these actors' location may be obtained in *Appendix G*.

It is important to make clear that the actors involved far exceed the ones presented. The process also involves a variety of technological companies and retail business that are engaged in the process, as they are responsible for it according to the extended producer responsibility.

Further, many recycling companies or business associations work subordinated to the companies mentioned, as it is the case of El-Kretsen. As it was not possible to have access to all companies related to the ones quoted, it is important to have in mind that they also have important roles to play.

5.5 Final considerations on the Swedish case

The Swedish system is very notable for its efficiency. One of the main strengths identified in the Swedish case was the cooperation strategy for waste management between local authorities and producers. While local authorities are in charge primarily for collecting the waste and informing the population, the producers are responsible for transporting, treating and recycling the products. Working together makes it possible to obtain such an efficiency in the process.

Another point to consider about the Swedish system is the strong civic support. In order to achieve a high level of efficiency in the process, it is mandatory to have a serious engagement of the population for obtaining an effective level of products' collection. By

making the population aware of the risks of Waste Electrical and Electronic Equipment, the importance of recycling it and by finding ways to facilitate its disposal, the system may obtain a high rate of collection.

Lastly, it is interesting to elucidate that the Swedish system has a nationwide collection system runned by El-Kretsen, a company owned by diverse business associations. Such system enables the technological companies to be associated with this nationwide system by paying fees according to their presence in the market. One of the barriers present for the technological companies to participate in the process is that the recycling process is not part of these companies' core business. Therefore, it is usually necessary very high costs from the companies to establish a collection and recycling system and it may not be economically profitable for them. By having a specific company that has the recycling system of electronics as its core business, it sounds logic that it is possible to achieve higher rates of collection than the decentralized process, while also bringing better financial results.

All in all, the Swedish example shows that it is possible, yet no so easy, to bring together the various stakeholders into a new behavior and cooperation dynamics for settling and conforming to *new rules of the game*. It also demonstrates that the creation of such collective rationality requires a combination of coordination mechanisms (regulations, monitoring and eventually penalties; information, learning and knowledge creation and dissemination; incentives and participation; cultural norms; mutual adjustment) that create room for, and progressively consolidates the needed *institutional proximity* for facing environmental challenges.

Table 1 brings a summary of the main points identified in the Swedish case.

Sweden	
Ecological footprint X Biocapacity	* Positive scenario: Biocapacity is higher than the ecological footprint. * Observation: The biocapacity is on a very small decline throughout the years.
EEE put on the market	28.7 kg per inhabitant on 2012 (STEP, 2015)
E-waste generated	24.86 kg per inhabitant on 2012 (STEP, 2015)
Is there a law towards e-waste management? Which one?	Yes. The Waste Electrical and Electronic Equipment - WEEE Directive (first version from 2003) work at the national level within the European Member States.
Does the law establishes the extended producer responsibility?	Yes.
Is there a law to phase out specific hazardous substances in the production of electronics? Which one?	Yes. The Restriction of Certain Hazardous Substances - RoHS Directive (first version from 2003) work at the national level within the European Member States.
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)	290 municipalities, Swedish Environmental Protection Agency (Swedish EPA), Swedish waste management and recycling association (Avfall Sverige), nationwide recycling system for collection and recycling of e-waste (El-Kretsen), recycling companies or business associations subordinated to El-Kretsen, Elretur system with about 1000 collection points, technological companies and retail business.
Main strengths identified	* The country works under the WEEE and RoHS Directives from the EU, which establish many guidelines. * The system is notable for its efficiency. * Cooperation strategy for waste management between local authorities and producers. * Strong civic support. * Environmental awareness. * Nationwide collection system of e-waste (El-Kretsen). * Very small quantity of WEEE is exported to other countries.
Main weaknesses and uncertainties identified	* Some e-waste still falls outside the system, with no knowledge about its treatment destinations and conditions. * The population very often stores the devices after end-of-life. * Sometimes the WEEE is discarded erroneously as regular waste.

Table 1: Summary of the Swedish case

(Source: Author)

6 THE FRENCH CASE

6.1 French ecological footprint

Figure 12 shows the ecological footprint of France, compared to its biocapacity, from 1961 to 2011. Completely different from the Swedish scenario, France has a much lower ecological footprint, but at the same time an even lower level of biocapacity, which makes its situation a negative one in terms of human demand on the Earth's ecosystems.

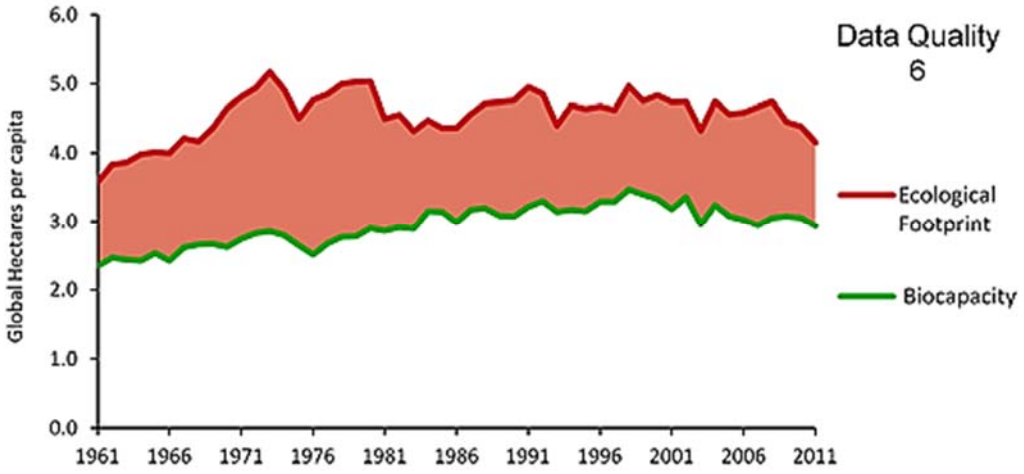

Figure 12: Ecological footprint X biocapacity in France

(Source: Global Footprint Network, 2015)

In the case of France, it is interesting to explain that, although the biocapacity has not changed so considerably throughout the years in comparison to its ecological footprint, the consumption demands exceed its biocapacity. This deficit may indicate a potential risk for the French economy, considering the limits of resources that the world already faces today and will face even more in the future.

6.2 Electronic waste scenario in France

France

Overview of e-waste related information

Subject	Unit	Year	Amount	Source
Population	(total inhabitants in million)	2012	63.42	IMF WEO
Purchasing Power*	(USD per Inhabitant)	2012	35,519.57	IMF WEO
EEE Put on Market*	(kg per inhabitant)	2012	25.81	UNU (Jaco Huisman)*
	(total in metric kilotonnes)	2012	1,636.76	UNU (Jaco Huisman)*
E-waste Generated*	(kg per inhabitant)	2012	21.09	UNU (Jaco Huisman)*
	(total in metric kilotonnes)	2012	1,337.24	UNU (Jaco Huisman)*

Figure 13: Overview of e-waste related information in France

(Source: STEP, 2015)

Figure 13 has been taken from the E-waste World Map and shows the case of electronic waste in France. By comparing it with the previous case of Sweden and the next case of Brazil, France shows to be between both countries in every aspect. With a population of 63.42 million inhabitants in 2012, the purchasing power per inhabitant of the French population is less than the Swedish.

From this, it sounds logic that the electronics put into the market per inhabitant are also less than in Sweden, although the total amount was much more than the Swedish case, which may be attributed to the higher population in France than in Sweden. The electronic waste generated per inhabitant is almost 4 kg less than in Sweden, with 24.86 kg in 2012. Nevertheless, the total electronic waste was almost at the Brazilian level, with 1,337.24 kilotonnes generated in 2012.

6.3 French management of electronic waste

The French legislation for electronic waste works under the WEEE Directive and RoHs Directive, as presented in the section *2.3 - The European legislations toward electronic waste*. The Decree n° 2005-829 from 2005 transposes the European law to the

French scenario. The *Agence de l'Environnement et de la Maîtrise de l'Energie* (ADEME), is responsible for managing the central register process for the producers of electronics.

The recycling of electronic waste is pointed out as strong tool for creating new jobs in France, as stated by the French Ministry of Environment (2014, p. 5):

> In France, over 5 years, WEEE recycling activities have created at least 30 new plants and more than 3,000 jobs (of which over 1,500 qualify as 'social economy' jobs) directly related to the sorting, depollution and recovery of metals and plastics from WEEE. The biggest of these plants employs 180 people, ensuring treatment of about 50,000 tons of WEEE per year, including fine-sorting of plastics.

There are four major eco-organizations to deal with the Waste Electrical and Electronic Equipment in the country, which are ERP, Eco-Systèmes, Ecologic and Récylum. These organizations are under the management of a private body that is accredited by the public French authorities to ensure mainly financial and administrative intermediation between the municipalities and the eco-organizations collective schemes, called OCAD3E (ABDI, 2013; Récylum, 2011). According to ADEME (2013, p. 7), the OCAD3E is "a certified co-ordinating body of WEEE and a common platform for four authorised WEEE Compliance Schemes, which connects local authorities with WEEE Compliance Schemes and supervises the overall WEEE stream".

As the producers are responsible for the appliances that they put in the market, Ecologic (2013) states that, as one of the members of the OCAD3E, the producers may sign up to Ecologic and delegate their legal responsibility for the recycling process. According to the same report, more than 1,000 producers are affiliated to this eco-organization.

In line with the WEEE Directive, the eco-organizations collective schemes in France should:

> […] encourage efforts towards the eco-design of household electrical and electronic equipment, particularly by reducing the hazardous substances that they contain, by facilitating their subsequent repair and re-use and by increasing their recycling and recovery potential (Récylum, 2011, p.40).

Therefore, they foster initiatives aligned with the circular and green economy principles seen in the literature review of *Part I*.

The eco-organizations become responsible for the e-waste the moment they remove it from the collection points. While OCAD3E finances the collection of e-waste,

the eco-organizations are in charge of dealing with the collection operational guidelines (ABDI, 2013).

Récylum (2011) is one of the four founder members of the OCAD3E and is the only eco-organization that is in charge of the collection of lamps. As one of the OCAD3E participants, Récylum (2011) financially supports every quarter the regional authorities taking part in the used lamps collection, in line with the article R543-181. Further, it participates in consultation groups together with social bodies within the OCAD3E sphere, in order to improve the eco-design and the general public awareness.

The members of OCAD3E should take part in the household waste collective schemes initiatives, so that to improve the integration and efficiency in the process. According to Récylum (2011, p. 54), this participation involves:

> Communication: annual programme perception survey; national WEEE information day "Tournée des DEEEglingués"; common database of collection points. Promoting eco-design: drafting of a bilingual guide to eco-design; impact of eco-design on upstream fee scales. Common technical studies: studies of PCBs potentially present in WEEE; measurement of the programme's carbon footprint; measurement of waste decontamination; social indicator of jobs created by the programme.

According to ADEME (2013), the Waste Electrical and Electronic Equipment may be discarded either at local waste collection centers from the local public authorities or at retailers' collection points, this last one depending on if this service is offered by the retailer. The used electronics may also be given to social companies.

The local collection may happen by both the local public authorities or by the retailers. Within the local public authorities, one of the collection systems is by the collection centers. According to ADEME (2013, p. 19), "OCAD3E identified around 4000 waste collection centres 'active' in 2012, covering between 61 and 62 million inhabitants, and representing 68% of WEEE flows collected by household Compliance Schemes in 2012". Besides the collection centers, the process may also happen within the local public authorities by door-to-door or upon request. The door-to-door process sometimes happens at pre-established dates and times, or even mixed with the other waste flows. The process upon request happens when the consumer calls the local public authority for the service, which usually comes the following day with a pick-up van.

The collection also happens by the retailers, to which the online sales represent an important portion. As stated by ADEME (2013, p.20):

> Online or in shops, retailers are obliged to accept the free return of used appliances when they are replaced with a new equivalent product. This is what is called a “one-for-one” obligation. In fact, the person in charge of delivering the new product is also responsible for returning the old one to the producer.

When not replaced by a new product, it is up to the retail to offer the service or not. Retailers have a very important role in the collection of e-waste, with a representation of 26% of the collection flow within the compliance schemes. In 2012, it was registered 21,928 collection points settled by distributors and 19,808 pick-up points taken by the WEEE Compliance Schemes, out of which 8,855 were active (ADEME, 2013).

When the electronic product is still in fare conditions of use, another option is the reuse, to which the French system has a special approach. Some examples of reuse operations are second-hand shops, junk shops, consignment shops, and online resale. This process involves a preparation or a control operation, so that to be resold after the refurbishment. The reuse sector has mainly three networks, which are the ENVIE Federation, Emmaüs and the *Réseau des Ressourceries*, besides other companies and charities that work with the municipalities to recover the goods. Some products that are in good conditions are also exported to developing countries to be used in educational programmes and charities (ADEME, 2013). Just as elucidated in the Swedish case, although this is an interesting strategy in the short term, it may causes some problems when the product comes to the end-of-life, due to the recycling difficulties in the developing countries.

The e-waste collected at either public local collection sites or by retailers usually goes to a regional platform, according with the e-waste compliance schemes, to be regrouped and sorted. After this process, the Waste Electrical and Electronic Equipment goes to the treatment facilities spread across France, which were 215 in 2010 (ADEME, 2013). *Figure 14* shows the distribution of the e-waste treatment centers in the French territory, according to the waste stream type.

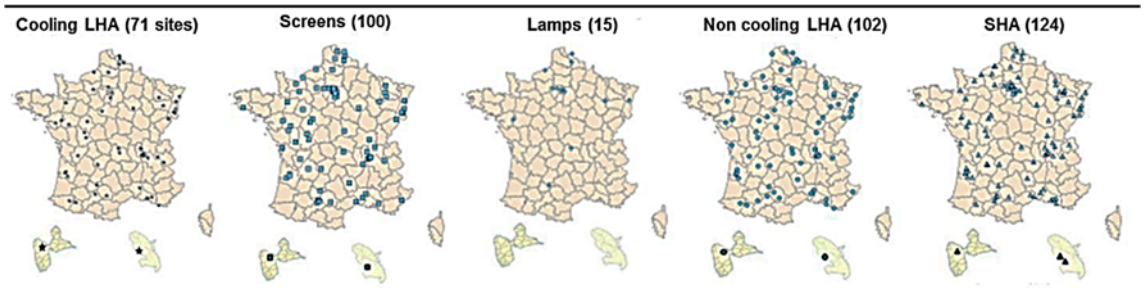

Figure 14: Distribution of WEEE treatment centers in France

(Source ADEME, 2010 apud ADEME, 2013)

After going to the treatment centers, the e-waste goes through a variety of process, to which ADEME (2013) points out the main ones and the number of sites doing each type of treatment: preparation for reuse (with 22 sites), depollution (more than half of the e-waste treatment sites), dismantling (108), shredding operations (51 installations) and, finally, physic-chemical treatment (6 sites).

An important role in the French recycling system is attributed to the scrap metal collectors. ADEME (2013) states that there are 2,000 metal collection sites in the country, 1,000 being members of the *Fédération des entreprises du recyclage* (FEDEREC) and representing the huge majority of the market. They collect, sort and sell the metals and, in order to be able to receive the e-waste, must have a treatment contract with the e-waste compliance schemes.

One of the final parts of the process is done by the scrap metal shredders, which also must have a contract with the compliance schemes so to be able to depollute the cooling appliances. ADEME (2013, p.25) further specifies that these shredders installations "are concentrated in regions with a high urban density (Ile de France, PACA, Rhône-Alpes) and in border areas with Belgium and Germany".

Concerning the export of Waste Electrical and Electronic Equipment, France is an active country in the subject, most of the scrap metals going to Belgium, Germany, Italy, Spain and Luxembourg. From the mixed scrap metal exported from France, around 10% of it represents e-waste, which is around 1.8 kg per inhabitant per year or 120,000 tonnes. Besides the e-waste exported to European within the legal framework, the Customs Directorate states that many containers are found by control operations with e-waste going to Africa or Asia, although no quantitative data has been obtained (ADEME, 2013).

The report from ADEME (2013) specifies that most of the e-waste is estimated to not being collected within the e-waste compliance schemes. In kg per inhabitant, this would represent between 10 and 16 kg not collected in the legal framework. From this, one of the wrong destinations pointed out by the study is the electronics that end up in residual household waste, without a proper recycling process, especially the small appliances that are easily disposed of. Another improper destination is the bulk waste containers of civic amenity sites, because usually this waste is not sorted and ends up incinerated or in landfills.

Further, there is a huge problem in France with theft and plundering of electronics from the waste collection centers. According to Eco-systèmes (2014), one of the problem in the municipal collection facilities is that the e-waste is usually a target of plundering, due to the high prices of the raw materials that it contains. To tackle this problem, Eco-systèmes offers its municipalities partners some technical assistance, like legal information and customized practical recommendations through an on-line tool to improve safeguarding.

Nevertheless, the plundering is still a huge problem in the recycling process of electronics in France, as it compromises up to 1.2kg per inhabitant, equivalent to up to 80,000 tonnes per year stolen from the municipal waste centers (ADEME, 2013). The estimation shows that the large electronic appliances are the ones mostly targeted, with up to 25% of the waste dropped off at the municipal centers being stolen. When it comes to the screens stolen from the facilities, it is estimated that, after being destroyed, only 10% of its weight is sold, meaning that 90% of the weighting product stolen is disposed of again.

ADEME (2013) points out to several factors that impair the e-waste compliance schemes process. Among many, there are the sorting errors and the alternative systems outside the legal framework of both collection and treatment. Besides, they also explain that the large waste collected by door-to-door initiatives usually is not sorted and ends up in landfills, which is not an appropriate destination for the electronic waste stream. It is also mentioned that, among the collection points provided for professionals and usually in need of specialized retailers, very few were active in 2012 in France. Lastly, many people still dispose of its e-waste as regular waste, which usually ends up in landfills.

6.4 Identification of the main actors involved in the French case

According to the case study, it has been possible to identify a variety of actors involved in the process. The *Agence de l'Environnement et de la Maîtrise de l'Energie* (ADEME) has its evidenced importance, especially concerning the register process for the producers. The process is runned by a national body, called OCAD3E, which usually has joint approaches with ADEME. OCAD3E has a fundamental importance, establishing a common platform and intermediation among some of the main actors, which are the eco-organizations and the municipalities.

The eco-organizations identified in the analysis that have a key role to play in the collection and recycling process are ERP, Eco-Systèmes, Ecologic and Récylum, all working by a compliance scheme for the management of e-waste.

The municipalities also play an important role in the collection process of Waste Electrical and Electronic Equipment, as they participate in collective schemes organized by the eco-organizations and should provide specific collection centers for this specific waste. According to Cartes France (n.d), France has 36,682 municipalities, also called communes, in the metropolitan France. All the municipalities in metropolitan France are evidenced in *Figure 15*.

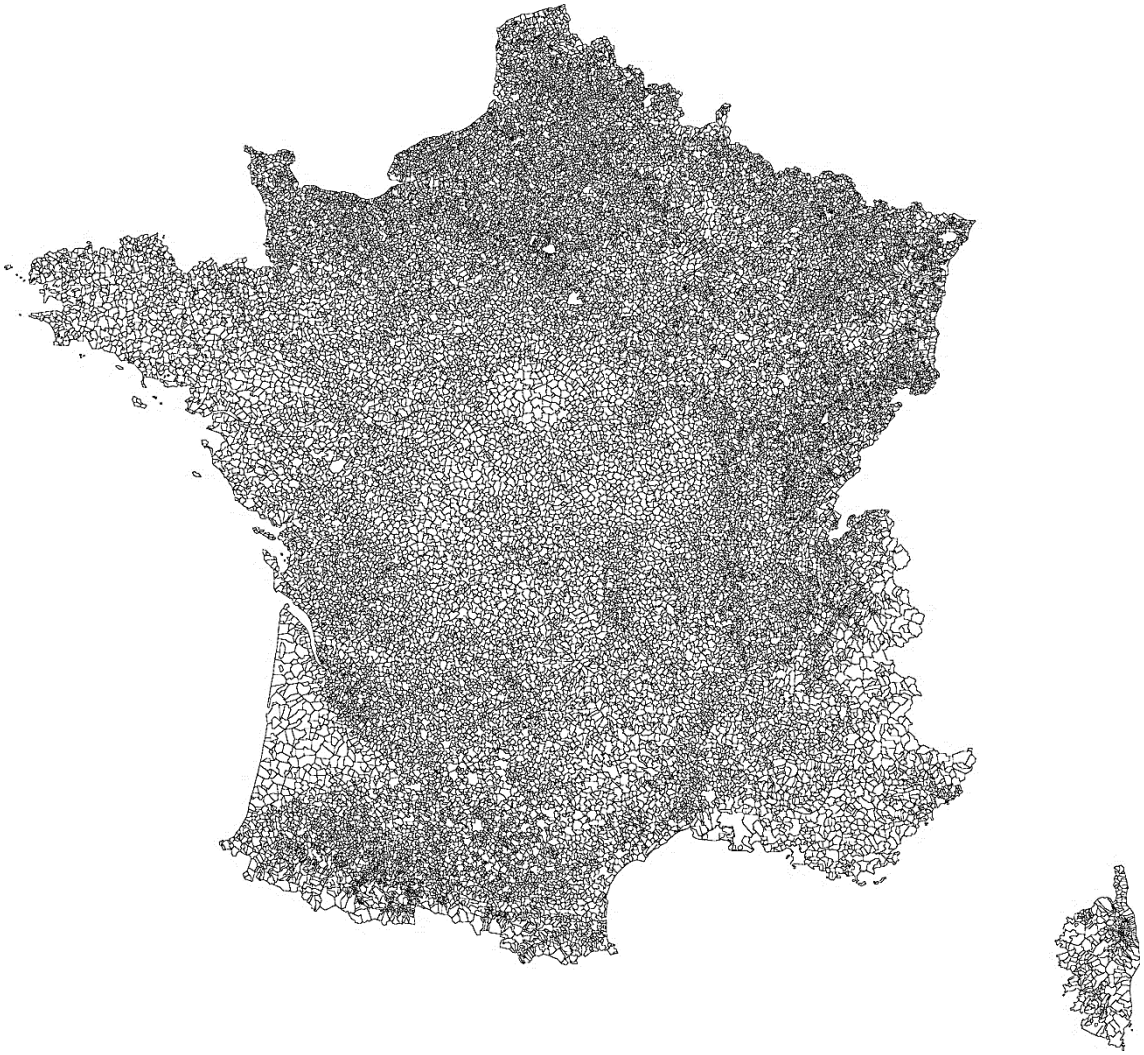

Figure 15: Municipalities (communes) in the metropolitan France

(Source: Cartes France, n.d)

Some of these municipalities have less than 1 km² (Cartes France, n.d), which demonstrates not only the high absolute number of municipalities in the country, but also its high density. This huge number of municipalities makes the collection of e-waste extremely complex, as it involves many actors in the waste collection stream. In this sense, the eco-organizations play a fundamental role, as they are in charge of connecting the different actors in their operation.

Another key player to the collection of e-waste is the retailer, which has the legal obligation of offering the collection service for someone who wants to replace its product.

When the electronics are still able to be used again, the main actors involved in the process are the social companies that receive the product and three networks entitled ENVIE Federation, Emmaüs and the *Réseau des Ressourceries*.

Besides, there are the treatment facilities, where a variety of processes take part and 215 have been identified. The scrap metal collectors also have a high presence on the French recycling system of electronics, working at around 2,000 metal collection sites. Some scrap metal shredders are also present in France, although in the mostly populated urban regions.

Just like the previous case study, the French one also has many more actors involved than the ones presented. The technological companies, directly connected to the process by the extended producer responsibility, as well as the other recycling approaches runned outside the compliance scheme of the eco-organizations are some examples.

6.5 Final considerations on the French case

The French case has proven to possess many tools to deal with the management of electronic waste. Under the European Directives for e-waste, the country has many similar tools for the collection and recycling system of electronics to the Swedish system. One of the main positive aspects identified has been the legal framework working with pre-established eco-organizations to deal with the problem together with the municipalities, having OCAD3E as the main body to establish the proper relations among actors. Similar to the Swedish system, producers of electronics may delegate their legal responsibility concerning the extended producer responsibility to the eco-organizations, so that they may focus on their core business. All the eco-organizations have shown to be well oriented and with proper policies, from what the various reports have shown.

Even so, as evidenced in *Part I (2.2 - The situation towards electronic waste in Europe)*, the French system does not have an equivalent efficiency in the process as the Swedish system previously analyzed. From this, one of the main aims in the French case has been to identify the main hindrances in the process.

An aspect that must be emphasized is the export of electronic waste. Although much scrap metal is exported to neighbor European countries, much of that is also

exported outside the legal framework to developing countries, were the process is usually made with no proper conditions and bringing many environmental problems.

Further, a huge problem identified in the French system has been the theft and plundering of Waste Electrical and Electronic Equipment from the collection centers, achieving high percentages of collected products being stolen. This does not only represent a problem to process' efficiency, but also a loss of money when it comes to all the costs of collection. Besides, it leads to rework, as much of the pieces with a low price in the market is not sold by the thieves, later returning to the collection process.

Another point is the lack of population's awareness to what the collective schemes are concerned. Although many actions appear to be in practice, much of the electronic-waste is erroneously discarded as regular waste, which hampers the separation process, usually having the landfills as wrong final destination.

From both the exports and the plundering issue, it is concluded that more security policies and practices should be implemented by the French system. Such security approaches could then lead to a more efficient process. Although not explicit in the reports, from the high rates of plundering identified, it may seem logic that some people feel afraid of disposing their products in the collective centers due to data leak. Therefore, the need of raising awareness in the population would be connected to also raising the security measures.

Table 2 brings a summary of the main points identified in the French case.

France	
Ecological footprint X Biocapacity	* Negative scenario: Ecological footprint is higher than the biocapacity. * Observation: The biocapacity is on a small rise throughout the years.
EEE put on the market	25.81 kg per inhabitant on 2012 (STEP, 2015)
E-waste generated	21.09 kg per inhabitant on 2012 (STEP, 2015)
Is there a law towards e-waste management? Which one?	Yes. The Waste Electrical and Electronic Equipment - WEEE Directive (first version from 2003) work at the national level within the European Member States.
Does the law establishes the extended producer responsibility?	Yes.
Is there a law to phase out specific hazardous substances in the production of electronics? Which one?	Yes. The Restriction of Certain Hazardous Substances - RoHS Directive (first version from 2003) work at the national level within the European Member States.
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)	36,682 municipalities, Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), National body for coordination of eco-organizations (OCAD3E), eco-organizations (ERP, Eco-Systèmes, Ecologic and Récylum), networks for reuse (ENVIE Federation, Emmaüs and the Réseau des Ressourceries), 215 WEEE treatment facilities, scrap metal collectors at around 2,000 metal collection sites, retailers.
Main strengths identified	* The country works under the WEEE and RoHS Directives from the EU, which establish many guidelines. * Many tools and organizations, with a good framework to deal specifically with the e-waste. * Nationwide coordination system of e-waste (OCAD3E).
Main weaknesses and uncertainties identified	* Some e-waste still falls outside the system, with no knowledge about its treatment destinations and conditions. * Lack of security measures, with high rates of theft and plundering of WEEE from the collection centers. * A considerable quantity of WEEE is exported to other countries, including developing ones. * Lack of population's awareness, with WEEE being many times discarded erroneously as regular waste.

Table 2: Summary of the French case

(Source: Author)

7 THE BRAZILIAN CASE

7.1 Brazilian ecological footprint

Figure 16 shows the ecological footprint of Brazil, compared to its biocapacity, from 1961 to 2011. Different from the two previous case studies, Brazil has a small ecological footprint, which is usually characteristic of underdeveloped or developing countries. With many natural resources that are known worldwide, Brazil has a higher level of biocapacity than its ecological footprint, which makes its situation a positive one in terms of human demand on the Earth's ecosystems.

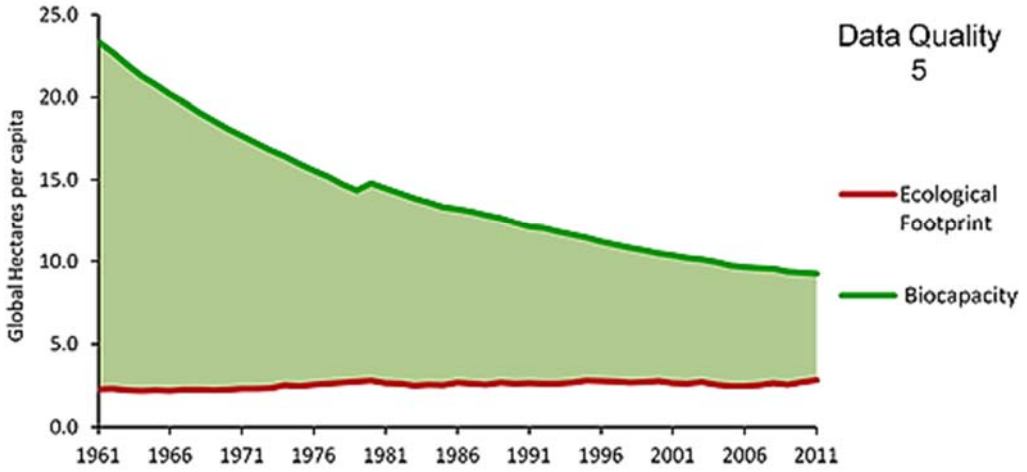

Figure 16: Ecological footprint X biocapacity in Brazil

(Source: Global Footprint Network, 2015)

What is extremely relevant to consider in the Brazilian scenario is the change of biocapacity throughout the years. In 1961, Brazil's biocapacity was almost 10 times its footprint, meaning the consumption demand of the Brazilian's residents could be met by using approximately a tenth of the ecosystem's capacity. Nevertheless, there has been a rapid reduction of its net ecological surplus throughout the years, while its per capita consumption has had minor changes. By 2011, Brazil's biocapacity was less than 4 times its footprint. Attention should be given to this point, in order for the Brazilian scenario not run into an ecological deficit in the next decades.

7.2 Electronic waste scenario 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)*

Figure 17: Overview of e-waste related information in Brazil

(Source: STEP, 2015)

Figure 17 has been taken from the *E-waste World Map* and shows the case of electronic waste in Brazil. By comparing with the two previous cases, it is evident that Brazil has a much higher population than the others. On the other hand, the purchasing power per inhabitant of the Brazilian population is far lower than the other European countries analyzed. From this, it sounds logic that the electronics put into the market per inhabitant are also less than in France and Sweden and, consequently, the electronic waste generated per inhabitant is also less, which was 7.06 kg in 2012. Nevertheless, considering the high number of the Brazilian population, the total electronic waste generated in 2012 was higher than the other countries analyzed, with 1,387.85 kilotonnes.

According to The World Bank Project Report (2012), Brazil has the fifth biggest global electronic and IT market, being after China, United States, Japan and Russia. The same report states that the Brazilian electronic and electrical industry contributes to 3.5% of the GNP and is rapidly growing. The ABINEE's membership, which is the national association for electrical and electronic professional manufacturing sector and represents more than 90% of this industry sector, had a growth of 11% of revenues in 2010.

7.3 Brazilian management of electronic waste

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 emergent 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 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.

There is not a specific regulation for only the electronic waste at the national level 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. 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 (2010) 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 need 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.

As described in the article 3 (chapter II) of the PNRS (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.[5]

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 […].[6]

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. 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.

Considering that the *National Solid Waste Policy* (PNRS) is not specific for the electronic waste, one of its main goals was that, by August 2014, all open-air dumps should no longer exist, which is a huge environmental problem in Brazil, especially in the big cities. From the law, all waste from the open-air dumps should be transferred to

[5] 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.

[6] 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 [...]

sanitary landfills in the maximum period of 4 years. Although this is far from what has happened, many initiatives have been on course as result of this legislation, which imposed fines for the municipalities that did not implement the measure on time. On the other hand, considering the inability from the Brazilian municipalities to accomplish this measure on time and the lack of founding, many municipalities have asked for more time for implementation. This possibility of deadline extension is currently being discussed.

Similarly 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 (2010) gives special attention to the role of cooperatives in the waste management. In Brazil, especially when it comes to waste management, the cooperatives and the waste collectors have a very important role and are usually composed of a population's portion with low income.

It is interesting to mention the work of Schneider et al (2014) about the activity of recyclable waste collectors in Brazil. From a literature review of the Brazilian publications on the subject, the authors concluded that, although most of the articles demonstrate the high importance of the collectors activity in Brazil, most of them clearly state that their situation is extremely vulnerable, at both the social and the economic sphere, suffering from numerous deficiencies. This situation results in prejudice, marginalization and exclusion of such individuals from the rest of the society. Schneider et al (2014) state that, just like the developed countries, Brazil needs to develop an integrated approach to minimize the environmental impacts, as well as more innovative approaches that are able to manage high amounts of waste.

According to article 18 of the PNRS (2010), the municipalities that implement the selective waste collection in partnership with cooperatives or other kind of association that works with collectors of reusable and recyclable materials composed by low income individuals will 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 is the case of the electronic waste.

The article 37 of PNRS (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, will 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 that operate 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* will serve as an information tool for the *National System of Information on Solid Waste Management* (SINIR). The SINIR will work under coordination of the Ministry of the Environment and will 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, which will make it possible to monitor and evaluate the efficiency in the process, analyze 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 Project Report, 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 Waste Electrical and Electronic Equipment 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 Project Report (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 runned by software companies, called *Reciclação* and *Assespro Rio,* which aim at raising awareness in the population about the importance of a proper disposal, in addition to collecting, rebuilding and donating electronics (The World Bank Project Report, 2012).

It is important to mention that, as stated by The World Bank Project Report (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.

In 2013, it was established a norm from the *Brazilian Association of Technical Standards*, the ABNT NBR 16156:2013 (ABNT, 2013) with requirements for the activity of reverse manufacturing of electronic waste. 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.

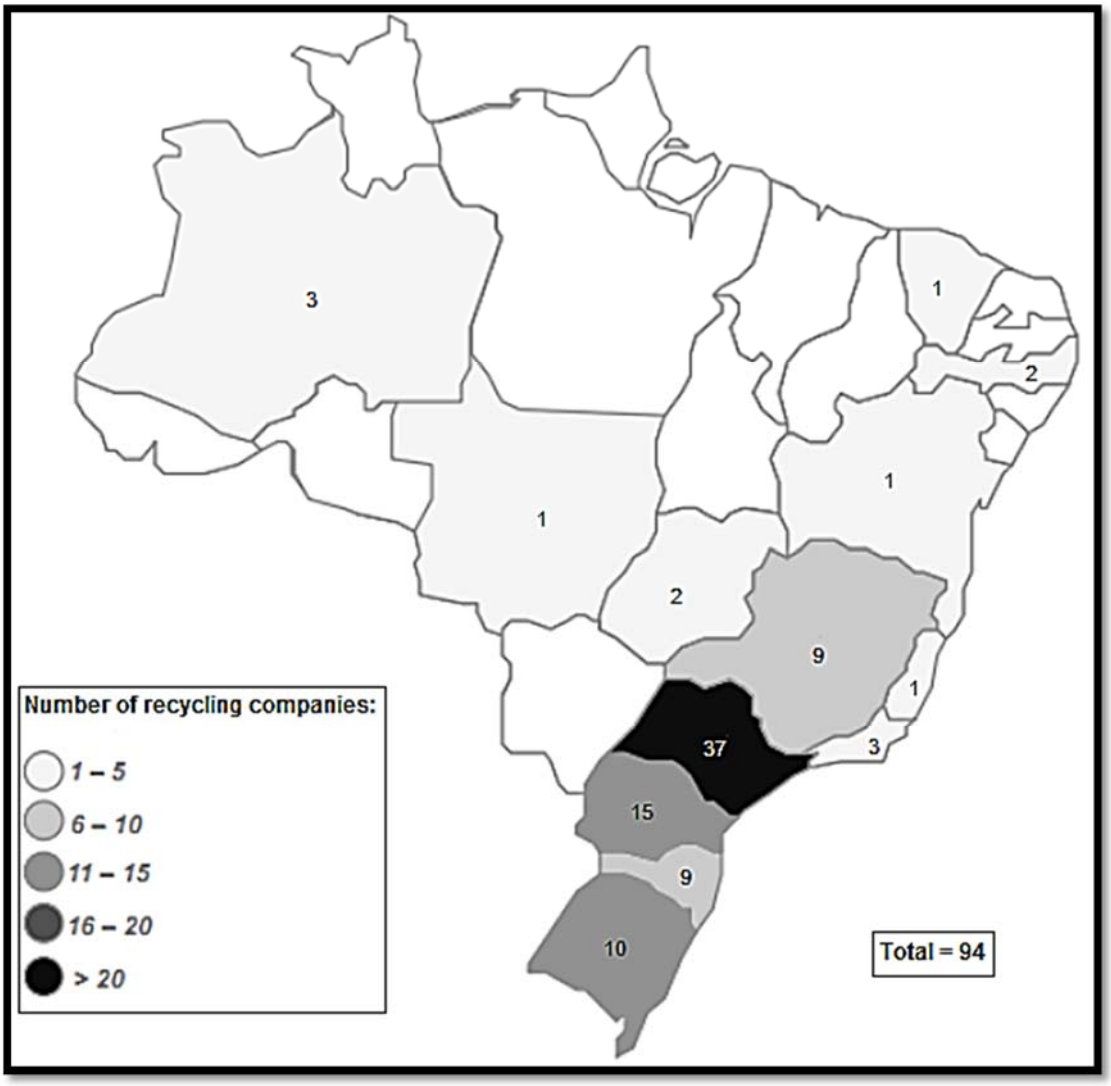

Figure 18: WEEE recycling companies acting in Brazil

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

After the collection, the electronic waste is transported to recycling facilities. *Figure 18* shows the number of recycling companies of Waste Electrical and Electronic Equipment in each Brazilian state. The state of São Paulo has the highest number for this specific waste, with 37 recycling companies of electronic waste. It is relevant to mention that the metropolitan area of São Paulo is, by far, the mostly populated metropolis in Brazil, as well in the global scenario.

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 (*Appendix D*) 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 the *System of Analysis of Foreign Trade Information*, called AliceWeb, (apud ABDI, 2013), more than 20,000 tonnes of waste that potentially came from electronic products were exported in 2011.

It is possible to observe from the case study 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 Project Report (2012), one of the challenges concerning Waste Electrical and Electronic Equipment 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 that it has one of the biggest electronic market in the world.

7.4 Identification of the main actors involved in the Brazilian case

As it has been pointed out during the case study, Brazil relies today on a 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.

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. As it may be seen in *Appendix D*, Brazil has 26 states and 1 federal district. It has 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 19.*

Figure 19: Municipalities in Brazil

(Source: Adapted from IBGE, 2015)

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, the technical assistance shops and the recycling cooperatives also have their importance in the process.

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.

Lastly, it is important to consider the essential part of the technological companies in the Brazilian process of recycling. Just as the European cases, 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 this specific product are responsible for providing a proper way of collecting this end-of-life product and give it an environmentally friendly final destination.

7.5 Final considerations on the Brazilian case

In the Brazilian case, it has been 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 recent law, particularly if compared to the Swedish law that started to prepare national legislation for the electronic waste management already in the late 1990's. By taking into consideration what has been discussed in the literature review about the need of long and lasting planning systems, together with a collaborative approach, it is easily observable that Brazil has a long path to follow, in order to achieve a desirable level of collection and recycling of Waste Electrical and Electronic Equipment. Further, it is important to consider that much of what is proposed by the PNRS, although ideally relevant, is not yet working in practice.

Another point to consider in the Brazilian case 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 consider 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 Brazilian 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 may benefit the collectors, as they will obtain a better price for the electronic scrap.

Another barrier is the lack of infrastructure and technology. Although with high rates of e-waste production, Brazil 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. The country must study about the 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 in the Brazilian case.

Brazil	
Ecological footprint X Biocapacity	* Positive scenario: Biocapacity is much higher than the ecological footprint. * Observation: The biocapacity is on strong decline throughout the years.
EEE put on the market	10.53 kg per inhabitant on 2012 (STEP, 2015)
E-waste generated	7.06 kg per inhabitant on 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.
Is there a law to phase out specific hazardous substances in the production of electronics? Which one?	No.
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, distributors, importers, retail business, the technical assistance shops 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.
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 the 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.

Table 3: Summary of the Brazilian case

(Source: Author)

8 FINAL CONSIDERATIONS OF PART II

Part II of the present research has brought the case studies of Sweden, France and Brazil, concerning the urban planning approaches toward the electronic waste management. By studying different countries, it has been possible to draw some consideration on the subject.

Table 4 brings a comparative analysis of all the three case studies presented in *Part II*. Taking into consideration the high complexity of analysis, comparing specific points in every case study makes it possible to have a proper understanding of the situation in each country.

By analyzing the relation between biocapacity and ecological footprint in every country, it has been possible to, right from the beginning, observe that the countries have completely different situations. In relation to the electronics produced and the electronic waste generated, while the European countries have a high production and a fast products' life cycle, Brazil has a much lower production and generation of electronic waste.

All three cases have legislation for the management of electronic products. Nevertheless, Brazil does not have a specific law for this issue, but instead a national policy that applies to solid waste and has some chapters addressing the subject. Both Sweden and France, as part of the European Members States, work under the WEEE Directive. While the WEEE Directive has been in practice and being enhanced since 2003, the Brazilian solid waste policy has only been approved in 2010. Unlike the European law that has the RoHS Directive, Brazil does not yet have a specific legal framework to phase out specific hazardous substances in the production of electronics.

All cases have established the principle of extended producer responsibility, making the producers of electronics a fundamental actor in the collection and recycling of the electronic waste. Besides, all cases also have the main approach of establishing guidelines at the national level for a joint approach with the municipalities.

Among the main actors identified that are involved somehow in the process of collection or/and recycling of electronic waste, many of them are similar in all cases. Some of them are the municipalities, Environmental Agency or Ministry, recycling companies or facilities and retailers. Special attention is given to the Swedish recycling system of e-waste (El-Kretsen) that runs the collection and recycling process in the whole

country, as well as the French coordination body (OCAD3E) and the eco-organizations that specifically work with the electronic waste stream in France.

Besides the European legal framework and the nationwide system present in Sweden and France, some main strengths have been identified in the European context. In the Swedish system, there is a high cooperation strategy between local authorities and producers, a strong environmental awareness and civic support. In the French system it has been possible to identify many tools and specific organizations to deal with the Waste Electrical and Electronic Equipment. Although Brazil has an interesting framework for managing the e-waste, much of what is proposed by the law does not yet work in practice.

Among the weaknesses in the process, many points have been identified in all case studies. For example, sometimes the Waste Electrical and Electronic Equipment is erroneously discarded as regular waste, having an improper destination. Another problem is that many people still end up by storing its devices at home after the end-of-life. Besides, in all case studies it was highlighted that some electronic waste ends up falling outside the legal system, thus not having data and knowledge about its treatment and destination, although illegal activities tend to export this specific waste to developing countries.

It is important to have in mind that, as will be treated further in *Limitations of the present work and suggestions for further research*, the comparative analysis does not comprehend a complete tool for analysis, as the complexity of each case far exceeds the available parameters studied. Instead, the case studies and the *Table 4* have the main goal of representing a broad analysis of each environment, so that to bring new insights on the subject and to propose possible paths for further study and process improvement.

	Sweden	France	Brazil
Ecological footprint X Biocapacity	* Positive scenario: Biocapacity is higher than the ecological footprint. * Observation: The biocapacity is on a very small decline throughout the years.	* Negative scenario: Ecological footprint is higher than the biocapacity. * Observation: The biocapacity is on a small rise throughout the years.	* Positive scenario: Biocapacity is much higher than the ecological footprint. * Observation: The biocapacity is on strong decline throughout the years.
EEE put on the market	28.7 kg per inhabitant on 2012 (STEP, 2015)	25.81 kg per inhabitant on 2012 (STEP, 2015)	10.53 kg per inhabitant on 2012 (STEP, 2015)
E-waste generated	24.86 kg per inhabitant on 2012 (STEP, 2015)	21.09 kg per inhabitant on 2012 (STEP, 2015)	7.06 kg per inhabitant on 2012 (STEP, 2015)
Is there a law towards e-waste management? Which one?	Yes. The Waste Electrical and Electronic Equipment - WEEE Directive (first version from 2003) work at the national level within the European Member States.		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.		
Is there a law to phase out specific hazardous substances in the production of electronics? Which one?	Yes. The Restriction of Certain Hazardous Substances - RoHS Directive (first version from 2003) work at the national level within the European Member States.		No.
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)	290 municipalities, Swedish Environmental Protection Agency (Swedish EPA), Swedish waste management and recycling association (Avfall Sverige), nationwide recycling system for collection and recycling of e-waste (El-Kretsen), recycling companies or business associations subordinated to El-Kretsen, Elretur system with about 1000 collection points, technological companies and retail business.	36,682 municipalities, Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), National body for coordination of eco-organizations (OCAD3E), eco-organizations (ERP, Eco-Systèmes, Ecologic and Récylum), networks for reuse (ENVIE Federation, Emmaüs and the Réseau des Ressourceries), 215 WEEE treatment facilities, scrap metal collectors at around 2,000 metal collection sites, retailers.	5,570 municipalities, Ministry of Environment, 94 WEEE recycling companies, distributors, importers, retail business, the technical assistance shops and the recycling cooperatives.

Table 4: Comparative analysis of the case studies

(Source: Author)

	Sweden	France	Brazil
Main strengths identified	* The country works under the WEEE and RoHS Directives from the EU, which establish many guidelines. * The system is notable for its efficiency. * Cooperation strategy for waste management between local authorities and producers. * Strong civic support. * Environmental awareness. * Nationwide collection system of e-waste (El-Kretsen). * Very small quantity of WEEE is exported to other countries.	* The country works under the WEEE and RoHS Directives from the EU, which establish many guidelines. * Many tools and organizations, with a good framework to deal specifically with the e-waste. * Nationwide coordination system of e-waste (OCAD3E).	* The National Solid Waste Policy (PNRS) establishes many relevant points, representing an interesting legal framework for the management of e-waste in the country.
Main weaknesses and uncertainties identified	* Some e-waste still falls outside the system, with no knowledge about its treatment destinations and conditions. * The population very often stores the devices after end-of-life. * Sometimes the WEEE is discarded erroneously as regular waste.	* Some e-waste still falls outside the system, with no knowledge about its treatment destinations and conditions. * Lack of security measures, with high rates of theft and plundering of WEEE from the collection centers. * A considerable quantity of WEEE is exported to other countries, including developing ones. * Lack of population’s awareness, with WEEE being many times discarded erroneously as regular waste.	* 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 the 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.

Table 4: Comparative analysis of the case studies (continuation)

(Source: Author)

FINAL CONSIDERATIONS OF THE RESEARCH

This Master Thesis has had the main aim of bringing new insights on how urban planning approaches deal with the electronic waste management in different contexts. Given the high complexity in which the subject is involved, a variety of subjects have been studied further, as a way of building a proper understanding of the broad scenario on focus.

Among the case studies, it has been possible to evidence that all the countries analyzed have the extended producer responsibility, which shows the growing concern to environmental practices and the need for the producers to be engaged in the process. The moment that the producers become legally and partly financially responsible for the electronic waste produced by them, there is a high probability that they will start to work toward more sustainable products and practices, as proposed by the green and the circular economy concepts.

One of the biggest problem identified in the case studies have been the lack of awareness of the population, which end up storing the electronic devices at home after the end-of-life or disposing of it as regular waste. Therefore, an improvement in the population's awareness is essential for an efficient system, as the population is one of the main actors involved in the process. Only by disposing of the products is possible to work in direction of a circular economy and only by disposing of it correctly is possible to do the proper recycling process.

Another key problem is that a lot of electronic waste still falls out of the legal system, much of it believed to end up at developing countries, without a proper management. Accordingly, it is not possible to obtain much data about its destination and treatment. From this, it is evident the need of security measures in the process as a whole.

All case studies have shown that the countries tend to establish laws for working together with different level of actors. Besides, a high number of actors have been identified in all cases, even though this does not comprehend a fool tool for analysis. By connecting these results from the case studies with what has been discussed in the literature review, there is the need of an institutional proximity, together with a collective learning among key actors for implementing an efficient system of collection and recycling of electronics.

Further, considering that the Waste Electrical and Electronic Equipment is still an emergent subject, this commitment of different actors becomes even more relevant, as it provides a way of sharing experiences, knowledge and converging values. Therefore, in order for the electronic waste management system to work, it is mandatory a true engagement, not only by the government, but by the population and the companies as well.

Lastly, it is pointed out that obtaining a highly efficient process of recycling of electronics is not a simple process and does not happen rapidly. Instead, it is the result of joint approaches focused on the long run, according to some points proposed in the strategic spatial planning part. By working together, focusing on measures that will last and having in mind that it will be a continuously learning process, it is possible to achieve good results.

LIMITATIONS OF THE PRESENT WORK AND SUGGESTIONS FOR FURTHER RESEARCH

The research conducted has an exploratory nature, in order to bring insights about a subject that is considerably new and on high demand of specialization. It is based on secondary data, taking into consideration mainly the financial and time restrictions. Therefore, the research has not included any interviews or surveys of any kind, neither has any primary data.

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 a tool for bringing insights on the subject.

The research has had the main goal of analyzing how the urban planning approaches deal with the electronic waste management in different contexts. It has analyzed mainly the public sphere, like governmental initiatives for this specific planning need, by studying especially laws and reports from each of the three countries. Therefore, this Master Thesis has not studied neither the private nor the population side with detail. Evidently, as discussed during the entire research, the electronic waste management is highly complex and involves a variety of actors, in addition to the public sphere. It is suggested, thus, future research to be conducted about the private sector and the population.

One path that could be taken in future research is to analyze how the private sector deals with the electronic waste management. The research could be conducted by both secondary analysis or by survey with the technological companies. Subjects that could be further developed are to describe the companies' initiatives in practice; to identify the level of communication and cooperation among the technological companies; and/or to study about whether companies perceive such subject as a threat of high costs or as an opportunity to obtain gains, while enhancing the company's image.

Another path suggested is to analyze the side of the population. The research could be conducted, for example, by surveys and/or interviews. Subjects that could be further discussed are to measure the level of population's awareness on the importance of having a different disposal for the electronic waste from the regular waste; and/or to study about

the population's knowledge about how to manage the electronic waste and the location of the collection points.

Further, the research has had a focus at the national level on each case study. Due mostly to time limitations, it has not been possible to deeply analyze all actions in a smaller scale in every country. Being so, another suggestion for further research is to study approaches in different levels, like at the state or municipality 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 a specific place, which could be a country. Such platform could identify all the collection points, as result of the joint research with companies. In addition, it could gather information about the 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 the electronic waste in a specific place.

Lastly, there is the idea of a nationwide collection system runned by a specific company, which is the case of El-Kretsen in Sweden. From this, future research could be carried out to analyze the economic and social feasibility of implementing such system in another country, taking into consideration the different context and realities involved.

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APPENDICES

Appendix A: Potential hazards of e-waste

Substance	Impacts	Where it can be found
Lead	Potential damage to the central and peripheral nervous systems, blood systems, kidney and reproductive system in humans. Negative effect on children's brain development.	TVs and monitors (especially CRT monitors); Small household appliances, IT equipment (circuit boards).
Cadmium	Toxic, with a possible risk of irreversible effects on human body.	TVs and monitors (CRT monitors); small household appliances, IT equipment (circuit boards).
Mercury	Damage to various organs, including the brain and kidneys, as well as the fetus.	Small household appliances, IT equipment (circuit boards, cell phones, etc.), fluorescent lamps including LCD backlights.
Hexavalent chromium/ chromium VI	Damage to DNA and extremely toxic in the environment.	Large household appliances (steel).
Plastics (including PVC)	Dioxins can be formed when PVC is burned within a certain temperature range.	Small household appliances, IT equipment (computers, cell phones, consumer electronics, etc.); TVs and monitors (CRT monitors), cables.
Brominated flame retardants (BFRs)	Impacts on neurobehavioral development.	Small household appliances, IT equipment (circuit boards); TVs and monitors (CRT monitors), plastics housings.
Barium	Short-term exposure to barium can cause brain swelling, muscle weakness, damage to the heart, liver, and spleen.	Small household appliances, IT equipment (computers); TVs and monitors (CRT monitors).
Beryllium	Classified as a human carcinogen as exposure to it can cause lung cancer.	Small household appliances, IT equipment (computers).
Toners	The black and color toners within the plastic printer cartridge may be carcinogen (esp. carbon black used).	Small household appliances (computer peripherals).
Phosphor and additives	Toxic to humans if touched.	TVs and monitors (CRT monitors).

(Source: The World Bank Project Report, 2012, p.3)

Appendix B: Geographic data about Sweden, France and Brazil

GEOGRAPHY			
	Sweden	**France**	**Brazil**
Location	Northern Europe	Metropolitan France: Western Europe	Eastern South America
Geographic coordinates	62 00 N, 15 00 E	Metropolitan France: 46 00 N, 2 00 E	10 00 S, 55 00 W
Total area	450,295 sq km	Metropolitan France: 551,500 sq km	8,514,877 sq km
Land area	410,335 sq km	Metropolitan France: 549,970 sq km	8,459,417 sq km
Water area	39,960 sq km	Metropolitan France: 1,530 sq km	55,460 sq km
Land boundaries	2,211 km	Metropolitan France: 2,751 km	16,145 km
Coastline	3,218 km	Metropolitan France: 3,427 km	7,491 km
Natural resources	Iron ore, copper, lead, zinc, gold, silver, tungsten, uranium, arsenic, feldspar, timber, hydropower.	Metropolitan France: coal, iron ore, bauxite, zinc, uranium, antimony, arsenic, potash, feldspar, fluorspar, gypsum, timber, fish.	Bauxite, gold, iron ore, manganese, nickel, phosphates, platinum, tin, rare earth elements, uranium, petroleum, hydropower, timber.
Current issues about the environment	Acid rain damage to soils and lakes; pollution of the North Sea and the Baltic Sea.	Some forest damage from acid rain; air pollution from industrial and vehicle emissions; water pollution from urban wastes, agricultural runoff.	Deforestation in Amazon Basin destroys the habitat and endangers a multitude of plant and animal species indigenous to the area; there is a lucrative illegal wildlife trade; air and water pollution in Rio de Janeiro, Sao Paulo, and several other large cities; land degradation and water pollution caused by improper mining activities; wetland degradation; severe oil spills.

(Source: Author, with data taken from INDEX MUNDI (n.d.))

Appendix C: Demographic data about Sweden, France and Brazil

DEMOGRAPHICS			
	Sweden	**France**	**Brazil**
Population (July 2014 est.)	9,723,809	Metropolitan France: 62,814,233	202,656,788
Age structure (2014 est.)	**0-14 years:** 16.9%	**0-14 years:** 18.7%	**0-14 years:** 23.8%
	15-24 years: 12.3%	**15-24 years:** 11.9%	**15-24 years:** 16.5%
	25-54 years: 39.2%	**25-54 years:** 38.6%	**25-54 years:** 43.7%
	55-64 years: 11.7%	**55-64 years:** 12.5%	**55-64 years:** 8.4%
	65 years and over: 19.8%	**65 years and over:** 18.3%	**65 years and over:** 7.6%
Population growth rate	0.79% (2014 est.)	0.45% (2014 est.)	0.8% (2014 est.)
Life expectancy at birth	81.89 years	81.66 years	73.28 years
Urban population (2011)	85.2% of total population	85.8% of total population	84.6% of total population
Rate of urbanization (2010-15 est.)	0.74% annual rate of change	1.1% annual rate of change	1.15% annual rate of change

(Source: Author, with data taken from INDEX MUNDI (n.d.))

Appendix D: Government data about Sweden, France and Brazil

GOVERNMENT			
	Sweden	**France**	**Brazil**
Government type	Constitutional Monarchy	Republic	Federal Republic
Capital's name	Stockholm	Paris	Brasilia
Administrative divisions	21 counties: Blekinge, Dalarna, Gavleborg, Gotland, Halland, Jamtland, Jonkoping, Kalmar, Kronoberg, Norrbotten, Orebro, Ostergotland, Skane, Sodermanland, Stockholm, Uppsala, Varmland, Vasterbotten, Vasternorrland, Vastmanland, Vastra Gotaland.	27 regions: Alsace, Aquitaine, Auvergne, Basse-Normandie (Lower Normandy), Bourgogne (Burgundy), Bretagne (Brittany), Centre, Champagne-Ardenne, Corse (Corsica), Franche-Comte, Guadeloupe, Guyane (French Guiana), Haute-Normandie (Upper Normandy), Ile-de-France, Languedoc-Roussillon, Limousin, Lorraine, Martinique, Mayotte, Midi-Pyrenees, Nord-Pas-de-Calais, Pays de la Loire, Picardie, Poitou-Charentes, Provence-Alpes-Cote d'Azur, Reunion, Rhone-Alpes. NOTE: France is divided into 22 metropolitan regions (including the "territorial collectivity" of Corse or Corsica) and 5 overseas regions (French Guiana, Guadeloupe, Martinique, Mayotte, and Reunion) and is subdivided into 96 metropolitan departments and 5 overseas departments (which are the same as the overseas regions).	26 states and 1 federal district*: Acre, Alagoas, Amapa, Amazonas, Bahia, Ceara, Distrito Federal*, Espirito Santo, Goias, Maranhao, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Para, Paraiba, Parana, Pernambuco, Piaui, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Rondonia, Roraima, Santa Catarina, Sao Paulo, Sergipe, Tocantins.

(Source: Author, with data taken from INDEX MUNDI (n.d.))

Appendix E: Economic data about Sweden, France and Brazil

ECONOMY			
	Sweden	**France**	**Brazil**
GDP - purchasing power parity (2013 est.)	393.8 billion USD	2.276 trillion USD	2.416 trillion USD
GDP - real growth rate (2013 est.)	0.9%	0.3%	2.3%
GDP - per capita (PPP) (2013 est.)	40,900 USD	35,700 USD	12,100 USD
Population below poverty line	NA%	7.9% (2011)	21.4% (2009 est.)
Labor force (2013 est.)	5.107 million	29.94 million	107.3 million

(Source: Author, with data taken from INDEX MUNDI (n.d.))

Appendix F: Telecommunications data about Sweden, France and Brazil

TELECOMMUNICATIONS (in millions)			
	Sweden	**France**	**Brazil**
Telephones - main lines in use (2012)	4.321	39.29	44.3
Telephones - mobile cellular (2012)	11.643	62.28	248.324
Internet users (2009)	8.398	Metropolitan France: 44.625	75.982

(Source: Author, with data taken from INDEX MUNDI (n.d.))

Appendix G: Geographical location of actors in the Swedish case

- Swedish Environmental Protection Agency (Swedish EPA)
  - Address: Prostgatan 2, S-211 25 Malmö, Sweden
  - Official website:: http://www.avfallsverige.se/
- Avfall Sverige: the Swedish waste management and recycling association;
  - Addresses: Valhallavägen 195, Stockholm or Forskarens Väg 5, Östersund
  - Official website: http://www.swedishepa.se/
- El-Kretsen: Nationwide recycling system for collection and recycling of electrical and electronic products.
  - Address: Klara Norra Kyrkogata 31, 111 83 Stockholm
  - Official website:: http://www.el-kretsen.se/english/

Geographical location of actors in the Swedish case

(Source: Author)

It is important to mention that this geographical location of actors only represents the companies' headquarters. As the Swedish system has a nationwide approach, it is evident that the area in which each actor acts is far beyond its geographical headquarters location. Just as an example, there is the system Elretur, managed by El-Kretsen, which as mentioned on the case study has about 1000 collection points around the country. Therefore, the spatial layout has been developed with the main goal of demonstrating the high complexity in which the Swedish system is involved. It does not represent, in any case, a complete tool for analysis of this scenario, but instead a tool for raising insights on the future of e-waste planning.