ANALYZING THE SUSTAINABILITY OF ELECTRONIC WASTE MANAGEMENT IN TORONTO, ONTARIO

By

© Tamara Tukhareli

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ABSTRACT

ANALYZING THE SUSTAINABILITY OF ELECTRONIC WASTE MANAGEMENT IN TORONTO, ONTARIO

Tamara Tukhareli
Memorial University

Advisor:
Professor Josh Lepawsky

Sustainable waste management plays a key role in achieving sustainable urban development worldwide. Currently, the rates of waste generation are on the increase with electronic waste comprising a significant portion of the total. This growth in the generation of electronic waste has led to the creation of sustainable management programs in a number of cities, including Toronto in Canada. An examination of the existing electronic waste management system in Toronto, Ontario has provided many insights into the structure of the relationships and the flow of the electronic waste within the area. This thesis analyzes the sustainability of the social networks and material flow networks that have developed within the Toronto electronic waste market. The data, collected from the field observations in the summer, points to a relatively uneven distribution of partnerships between the large-scale recycling corporations, government organizations, non-profit refurbishers and the informal recyclers. The examination also reveals a prioritization towards large-scale mechanical recycling over refurbishing and re-use of the electronics. The effect of such distribution of material and partnerships on the overall sustainability of the management system is discussed.

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List of Abbreviations

CMA – Census Metropolitan Area

EPR – Extended Producer Responsibility

EPRA – Electronic Products Recycling Association

EU – European Union

E-waste – Electronic waste

IT – Information Technology

NFP – not-for-profit

MOE – Ministry of the Environment

MFA – Material Flow Analysis

OES – Ontario Electronic Stewardship

ppm – parts per million

RCT – Renewed Computer Technology

RQO – Recycler Qualification Office

SNA – Social Network Analysis

UN – United Nations

WCED – World Commission of the Environment and Development

WDO – Waste Diversion Ontario

WEEE – Waste Electrical and Electronic Equipment

Chapter 1: Introduction

1.1 Background

Globally, the rates of waste production are increasing, with electronic waste comprising a large portion of the total. In Canada, over 120 000 tonnes of electronic waste was collected in 2012 (Electronic Product Stewardship, 2013). Sustainable management[1] of such vast quantities of waste plays a key role in the achievement of local and global sustainability (Seadon, 2010). More specifically, the successful development of local communities, such as urban centers, in part depends on sustainable, long-term management of waste electrical and electronic equipment (WEEE).

Currently, a number of different electronic waste management strategies are in place in various urban areas worldwide (Ongongo et al, 2011). Solid waste and electronic waste management share a number of key characteristics that impact the development of a sustainable management system. Generally speaking, the management systems that occur in many urban developed areas are centrally organized, with close relationships between the government and large-scale recycling corporations (Baud et al, 2001; Wilson et al, 2009; Scheinberg, 2011). Meanwhile, the smaller scale entrepreneurs, manual disassembly efforts and the informal sector are often not incorporated into the official management strategy (Baud et al, 2001; Wilson et al, 2009). According to the literature, each type of waste management sector (manual disassembly, large-scale recycling, small scale an even

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[1] For the purpose of this thesis, sustainable management is defined as a long-term management strategy that equally addresses the environmental, social and economic aspects of local and global community resilience.

informal) has an ability to impact the overall sustainability of the waste management system (Baud et al 2001; Wilson et al, 2006; Scheinberg, 2011; Gutberlet, 2012; Velis et al, 2012 among others). The incorporation of each of these actors into the electronic waste management network can arguably affect the environmental, economic and social aspects of urban sustainability (Wilson et al, 2006; Hageluken, 2006). However, while more alliances (social interactions and flow of material) are generally developed between larger-scale recycling corporations and the urban government, the smaller-scale entrepreneurs and the informal processing sectors are often excluded and regarded with prejudice (Baud et al. 2001; Scheinberg, 2011). Evidently, this uneven distribution of partnerships can have a number of consequences on sustainable management of waste.

The role of various small sectors, including the informal recyclers, in solid and electronic waste management has become a source of recent interest in academia and popular media (Gutberlet, 2012, Lepawsky and Billah 2011, Wilson et al, 2009). Yet, a large portion of the discussions has been focused on the characteristics of these sectors in the developing countries. At the same time, the role of small-scale recycling and refurbishing, manual disassembly and even the informal sector has not been extensively discussed in the context of a developed, urban setting, such as the City of Toronto. Therefore, the objective of this study is to analyze the role that the actors (recyclers, refurbishers, government organization etc.) play in the current and future sustainability of the electronic waste management sector in The City of Toronto, Ontario, Canada. The 'ideal' image of sustainable electronic waste management is derived through the analysis of literature. The electronic waste management network is analyzed for the presence of environmental, economic and social characteristics of sustainability.

1.2 Purpose and Questions

The purpose of this study is to analyze the current and future sustainability of the electronic waste management sector in The City of Toronto, Ontario, Canada. The purpose will be addressed by answering the following research questions:

1) What is the structure of the electronic waste management networks in Toronto?
    a. What is the overall structure of social alliances and material flow within the e-waste management system in Toronto?
    b. What role do the various actors play in the development of a sustainable electronic waste management system?
2) How, if at all, could the sustainability of the existing electronic waste management system be enhanced?

A combination of quantitative and qualitative data are required to provide sufficient information to address the research questions. Thus, a mixed methodology involving both qualitative and quantitative data collection and analysis is used.

1.3 Research Location

While the majority of social research pertaining to electronic waste management has been situated in the developing world, there has been minimal research focused on similar analysis in developed urban centres like the City of Toronto. The role of the relationships between the large-scale, formalized management sectors, small-scale entrepreneurs, and the informal sector has not been studied in much detail in the context of local urban communities. A large portion of the existing urban waste literature focuses on the exploration of a sole sector of waste management, such as the informal processors. The recent interest in the informal waste sector can be likely attributed to the often-complicated political and economic situation surrounding it. The creation of informal or alternative economies through waste management has become a prevalent topic within academia. Gutberlet and colleagues explore the role of informal recyclers or 'binners' in poverty alleviation in Victoria, Canada (Gutberlet, 2009). Similarly, the potential of the informal recycling practices in cities in the United States is explored by Nas and Jaffe (2004). Nonetheless, it is evident that more research on the electronic waste management sector in an urban setting is necessary. Additionally, little has been done to merge the theoretical discourse of sustainability with the more practical application of electronic waste management. This particular research location will add to the development of a coherent discourse between electronic waste management and urban sustainability.

The City of Toronto currently hosts approximately 2 600 000 people of varying international backgrounds. Toronto also serves as a home to a diverse network of businesses, from small-scale entrepreneurs to large-scale corporations. The combination of residential, industrial and commercial sectors produce a large quantity of waste, a portion of which is represented by electronic waste. This type of waste has created a significant market for recycling and reuse. The electronic management sector in Toronto is represented by a combination of large and small-scale private businesses, non-profit organizations and informal processors. The management process of electronics is predominately overseen by the City of Toronto as well as the provincial government, via the Ministry of the Environment and Ontario Electronic Stewardship (non-profit organization). The general state of the management process, as well as the role of the variety of processors within the sector, appears unambiguous at first. Yet, the impact of the current network of e-waste actors on the sustainability of urban center is unclear. Insight into the details of the functionality of such a complex system could provide answers to the current and future system's capacity to enhance the sustainability of e-waste management. Toronto provides an excellent opportunity to explore these particular attributes of the existing waste management sector. The findings from this study can be extrapolated to similar situations to improve an overall understanding of urban waste management.

1.4 Thesis Outline

This thesis is presented in seven chapters: Introduction; Literature Review; Methodology; three Results chapters and Conclusion. Following the Introduction, the Literature Review Chapter develops a dialogue between the body of academic research on solid and electronic waste management as well as the discourse of urban sustainability. The conclusions drawn from the Literature Review are discussed within the Methods and Results of the research project. Chapter Three outlines the multiple methodologies used during data collection and analysis. The findings of the research are summarized in three Chapters. Chapters Four and Five address the research questions by describing and analyzing the roles of the key actors within the e-waste management system and their impacts on the system's sustainability. Chapter Six covers the research objective by analyzing the overall structure of e-waste management network in Toronto and its effect on sustainability. Finally, Chapter Seven draws conclusions on the current and future sustainability of electronic waste management in Toronto and provides recommendations for future research and policy.

Chapter 2: Literature review

2.1 Introduction

This chapter will address the topic of sustainable electronic waste management in an urban environment. It will begin by reviewing the broad concept of sustainability and proceed to concentrate on the issues of urban sustainability. The role of sustainable waste management in urban sustainability will be explained. The chapter will then proceed to discuss the issues associated with the realization of sustainable electronic waste management system in urban centres worldwide. The state of urban electronic waste management will be analyzed through the lens of three individual pillars of sustainability: environmental, economic and social sustainability. It will be my goal to demonstrate that sustainable electronic waste management is one of the key attributes to achieving social, economic and environmental sustainability in an urban setting. I will further argue that sustainable electronic waste management can and should be achieved through the means of co-operation between the formal waste management sector, the smaller-scale entrepreneurs and the informal sector.

It is important to note that the pillars approach has limitation in its ability to holistically address the issues at hand. The three categories (environmental, social and economic) have been criticized for not addressing all of the important topics. Additionally, the separate grouping of the pillars may lead to the division of interests rather than the creation of mutually supportive initiatives (Gibson, 2005). The above shortcomings of the pillars are recognized by the author and will serve as a basis for further recommendations in the final

Chapter. However, for the purpose of the analysis of the waste management system in Toronto, the author believes that the pillars approach does provide a good structure for the discussion.

2.2 The three pillars and the scale of sustainability

The term 'sustainability' was first introduced into common use by the Report of the World Commission on the Environment and Development (W.C.E.D): Our Common Future (also know as the Bruntland report), published in 1987. It was the intention of the report to highlight and provide plausible solutions to correct the dangers of environmental degradation, economic instability and social inequality at the time. However, the report's success in the application and enforcement of the suggested tactics worldwide has been widely questioned. Many have associated the failure in the implementation of the sustainability agenda to the ambiguousness of the definitions communicated by the report (Robinson, 2004; Johnston et al, 2007). The definition that is most commonly quoted from the W.C.E.D. Report is that of 'sustainable development'.

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." - Our Common Future, Sustainable Development, Chapter 2, paragraph 1

The above quotation has been criticized for its vagueness by many academics and politicians. The term itself has been said to be self – contradictory, with the words 'sustainability' and 'development' fostering different imperatives (Pezzoli, 1997; Robinson, 2004; Johnston et al, 2007). The necessity for the clarification of the term yielded hundreds of different definitions over the years (Johnston et al, 2007). Each different interpretation led to a set of differing actions and implementation into policy (Pezzoli, 1997). The uncertainty in terminology has in turn resulted in a multitude of debates regarding the meaning and application of 'sustainability' (Zhorel et al, 2012). Yet, one key discussion demonstrated the potential to simplify the discourse of sustainability.

The discourse of sustainability has often been broken down into the three pillars of sustainability (environmental, economic and social) for simplification.[2] The three pillars are said to be interdependent, such as long-term economic sustainability cannot exist without environmental and social sustainability and vice versa (W.C.E.D, 1987, Section 1, paragraphs 2 – 5). This particular point has been neglected in the years following the publication of the report. As a result, the pillars approach has been often unable to promote positive linkages between the three areas of emphasis (Gibson, 2005). Often, unequal priority has been allocated to the goals associated with one pillar of sustainability over the other (Cuthill, 2010; Demspey et al, 2011). Conflicts of interest have commonly arisen between the mandates of the three pillars. For example, at times, large-scale environmental conservation projects promote social injustice for the people residing in the local area (Marcuse, 1998). This inequality between the goals of sustainability has resulted in the creation of alternate criteria. For example, Gibson (2005) advocates for the core requirement of sustainability to be addressed through a group of eight principles. For the purpose of this research project, the pillar structure of the sustainability argument remains

[2] The segregation of the overarching topic into three pillars has likely stemmed from the Bruntland report itself. One of the report's first sections concentrates on understanding the interconnectedness between the "International Economy" (i.e. Economic sustainability), the "Environment" (i.e. Environmental sustainability) and "Development" (social sustainability) (W.C.E.D, 1987, Section 1, paragraphs 2 – 5).

useful as long as the interrelationship between the three (the environment, the social and the economic) is kept a priority. I argue that the conflicting prioritization between pillars could also be resolved by addressing the geographic scale of the debate pertaining to each pillar.

The geographical scale of sustainability, particularly when multiple goals are involved, is often difficult to identify. It remains obvious, however, that contrasting the mandates of social sustainability at a local level to that of environmental sustainability at a global level can only promote injustice (Woods, 2009). For example, while promoting the goals of sustainability on a global scale, such as general ecological preservation, the livelihoods of a local community may be placed at stake. Thus, in order to develop a coherent dialogue, the scale (individual, regional, national, international) at which the principles of sustainability are assessed must be similar. Otherwise, we are in danger of creating further inequality. The following section will argue that a more localized scale of sustainability could positively impact the application of sustainability to policy and planning.

In terms of scale, the most prominent discussion pertains to a 'global' vs. 'local' application of sustainability. The pro-global argument supports the idea of a more universal, centrally planned model of sustainability (Hanna, 2006). In this scenario, a common agenda for the realization of sustainability will be applied equally worldwide. According to its supporters, this approach would eliminate a certain level of confusion associated with the term (Hanna, 2006). However, it would also require a very uniform world. Since our planet hosts a great variety of cities, nations and communities of varying geographical and cultural characteristics, the above scenario would not be very useful. Furthermore, some have argued that following a single version of sustainability could prove fatal, as any single policy can hardly account for all the factors associated with such large-scale planning (Littig and Griebler, 2005). For that reason, the idea of community driven, individualistic sustainability is supported locally.

Local community participation has been long recognized for its importance in management strategies (Baud et al, 2001; Gottdiener and Budd, 2005; Seadon; 2010; Dempsey et al, 2011). Local citizens are better aware of their community's needs. As such, they are able to apply their knowledge to planning and management of their own communities. The local community has an opportunity to act both as the enforcer and the critic of policy. Contrastingly, if little opportunity is provided for local participation, policy implementation is certain to be more difficult. Local citizens are as capable of supporting an initiative they believe in as halting one that goes against their principles. This behaviour has been extremely successful with a number of grassroots organizations, where local communities have developed and implemented their own plans for achieving a sustainable future. Therefore, keeping sustainability planning to a more local scale can be critical for its success (Dempsey et al, 2011).

However successful the local sustainability movement has appeared at times, some suggest that collaboration between the 'global' and 'local' levels would be even more effective. Yet, creating a coherent planning relationship between the two may prove to be a challenge. Michael Woods (2009) calls attention to the disconnect between large-scale planning for 'global challenges' and rural community planning. We must keep in mind that projects intended to resolve global-scale problems often physically appear in local communities. Woods argues that many policies, often associated with global goals, like the provision of cleaner energy, neglect to take the local community perspective into account.

This separation of scales results in unhappy or damaged communities. At the same time, the goals of the policy and/or projects themselves are also jeopardized as they may depend on community participation. It appears that in order to succeed, policies and planning of 'global' scale need to think more local (Woods, 2009; Dempsey et al, 2011). Perhaps, 'global' sustainability can be achieved by concentrating on a more 'local' perspective.

2.3 Sustainable communities and urban sustainability

While keeping in mind the global context of the sustainability discourse, locally concentrated efforts are more likely to result in the fulfillment of the goals of sustainability. Through the creation of sustainable communities and cities worldwide, the sustainability ideals can in fact be applied and enforced globally. The following definition describes the key characteristics of a local sustainable community.

> "places where people want to live and work, now and in the future. [Sustainable communities] meet the diverse needs of existing and future residents, are sensitive to their environment and contribute to high quality of life. They are safe and inclusive, well planned, built and run and offer equality of opportunity and good service for all" (O.D.P.M., 2006, p. 12)

There are a number of key characteristics that need to be addressed to promote the development of a locally sustainable community. These include: meeting the needs of residence through provision of work; creating safe and inclusive environments and offering equality of opportunity for all. The following sections will describe potential pathways that will promote the implementation of the characteristics that are particularly prominent to this research project.

Arguably, in order to consistently meet the needs of existing residents, the community should strive towards self-sufficiency. Self-sufficiency is regarded as one of the key characteristics of a 'metabolism' of a sustainable urban centre (Broto et al, 2012; Rees, 2010). Urban metabolism analysis involves measuring the inputs and outputs of a city. By using the natural ecosystem as a model, the study of urban metabolism has synthesized an image (although mostly theoretical) of the ideal characteristics of a sustainable city. In theory, the city should only use enough resources so as to not stress the resource supply of its surrounding areas. Similarly, the city's outputs should be used within the boundaries of its 'hinterlands' and certainly not have a negative impact on the environment (Kennedy et al, 2007). While the realistic implementation of the above ‘ideal’ goal is questionable, it can nonetheless serve as an excellent target for urban sustainability. The current state of urban sustainability, however, deviates quite far from this image.

> "The metabolism of a typical modern city can be described as “linear” in that it extracts resources from beyond its boundaries, makes use of them within its boundaries to support urban activities, then deposits the resulting wastes in high concentrations back to the external environment" (U.N.H.S.P., 2012, Girardet, 2008).

The above scenario hardly mirrors the more cyclical metabolic pathways observed in nature. It would appear that in order to reproduce the above 'natural' system better, the city must either: a) produce wastes that are not harmful to the surrounding environments in any way or b) use-up the waste within the city/ hinterland boundary. To sum up, a sustainable city will only become sustainable when its resources and its waste are managed properly within its geographic area.

The necessary elements for the provision of self-sufficiency point to the crucial role of waste management within sustainable development of a community and/or and urban centre (Seadon, 2010). Through the implementation of 'urban metabolism' ideals, sustainable waste management can positively impact the environmental and economic objectives of sustainable urban development. However, it is important to remain critical while envisioning this 'ideal', self-sufficient urban centre.

It appears obvious that no city would be able to remain fully self-sufficient in the real world. In fact, it is unlikely that complete cyclical metabolism of waste and resources is desirable. The electronic waste industry, for example, is entangled in a complex web of international trade (Lepawsky, 2014). Similarly, it is hard to ignore the obvious necessity for the supply of certain types of material to geographical areas that lack that resource. Nonetheless, the author believes that the journey towards cyclical metabolism and self-sufficiency outweighs the tangibility of the final result. In other words, a community striving for self-sufficiency will likely undergo a number of positive changes that will promote local sustainability. Even if the final 'ideal' result is not reached, the measures that are implemented on the way will likely encourage the development of local environmental, social and economic objectives.

The development of a sustainable community also relies on the promotion of social sustainability characteristics (e.g. social equality and social justice). These factors can be in part addressed through sustainable waste management as well.

Globally, millions of individuals participate in waste management activities. Only a fraction of them, however, are recognized for their contribution to sustainable waste management. In general, many developed urban centres support formalized, centrally – organized waste management system (Ongondo et al, 2011). At the same time, nearly 2% of residents of developing areas, such as China, India and South America, participate in the informal scavenging and waste picking practice (Wilson et al, 2009; Medina, 2000). The two different sectors are arguably beneficial to the sustainability of global waste management. However, while more and more urban centres are striving to modify their waste management system to be exclusively 'formal', the informal sector is struggling to survive while coping with continuous prejudice (Baud et al, 2001; Gutberlet, 2009; Gutberlet, 2012, Wilson et al, 2009'; Wilson et al, 2006 and others). The informal sector participants are often badly exploited, paid very low wages (if anything at all), and their activities are often criminalized (Wilson et al, 2006; Scheinberg et al, 2011). In order to reach urban sustainability, social justice must be addressed with as equal of a priority as environmental degradation and economic efficiency.

In accordance with the characteristics of 'sustainable communities', every resident should be provided with 'equal opportunity' (O.D.P.M., 2006). "No exclusionary or discriminatory practices hindering individuals from participating economically, socially and politically" should occur (Dempsey et al, 2011). It should be highlighted that the successful implementation and enforcement of any management policies depends on the co-operation and support of the local community and in turn, the urban poor. Thus, the discrimination that is currently targeted at the informal waste sector in many urban centres must be addressed to support the development of sustainable communities.

> "...the sustainable development of cities will depend on close work with the majorities of urban poor who are the true city builders, tapping the skills, energies and resources of neighbourhood groups and those in the informal sector'" (W.C.E.D, 1987, Urban Sustainability section)

The above discussion points out the necessary components that may contribute to the formulation of a sustainable community and in turn promote global sustainability. Overall, it has been suggested that global sustainability can be realized through the creation of sustainable communities and cities locally. Many of the environmental, social and economic sustainability goals can be achieved through the implementation of cyclical metabolism ideals. However, the complete self-sufficiency of an urban centre is likely unattainable and perhaps also unnecessary due to the current dependence on the international trade of resources. Nonetheless, the journey towards self-sufficiency and urban sustainability can be expected to establish necessary positive change.

The key to reaching local and urban sustainability is in the even allocation of priorities between the environmental (resource management and proper disposal of waste), economic (supply of jobs and support of the local economy) and social (participation and inclusivity) goals. It has been argued that waste management can help achieve those goals by addressing each aspect of sustainability equally. Waste management has the capacity to alleviate environmental degradation and financial costs associated with waste disposal, while at the same time promoting social equality. Consequently, sustainable waste management can greatly contribute to sustainable development.

The following sections will focus on analyzing the capacity of waste management, and electronic waste management in particular, to meet the above criteria of sustainability. The analysis will proceed by assessing the necessary components of each individual pillar of sustainability. Particular attention will be paid to the equal integration of each pillar equally throughout the management system. The chapter will conclude by discussing the feasibility of the translation of the theoretical image of sustainable waste management in an urban centre into reality.

2.4 Environmentally sustainable electronic waste management

Ecosystem maintenance is the central goal of the environmental pillar of sustainability. Yet, it is hard to measure the vastness of the environment that can be affected by a certain action, like recycling or production of electronics. As a result, environmental sustainability is perhaps the most complex pillar to analyze. It is even more difficult to contain the scale of the analysis to a certain geographic area, like a city. Nonetheless, the urban metabolism approach described by Girardet (2008), Kennedy et al. (2007) and others may prove to be a useful tool for the analysis within this section.

In accordance with the previous conclusions, if a city were to be visualized as an organism with its own metabolism, then environmental sustainability may be achieved by ensuring that the city's metabolism remains within the boundaries of its own area and the area of its hinterlands (Kennedy et al, 2007). To expand further, the city should strive to use only the amount of resources that meet the natural capacity limits of its surroundings. Additionally, the city's outputs should be also used within the boundaries of its surrounding areas and not have any negative impacts on the environment (Kennedy et al, 2007). No matter how appealing the above ideas may appear in theory, there are many barriers to their realization. It is self-evident that most cities will likely never be able to achieve such a state of environmental sustainability. Nonetheless, even at this point, positive movement towards the said goals continues to occur in many different forms. It will be the purpose of this section to apply this discussion to the current state of waste and electronic waste management. Connections will be drawn between the theoretical image of environmentally sustainable electronic waste management and the reality of the practice as it appears right now. This section will start by reviewing the key environmental and health concerns associated with electronic waste management. Different types of recycling and waste management sectors and programs will be discussed. The section will conclude by comparing the practice to theory.

The primary area of concern associated with electronic waste is its sheer quantity. It is estimated that each resident within the European Union was producing between 14 and 20 kg of electronic waste in 2002 (United Nations University, 2007). It is safe to assume that this number could have grown exponentially over the last decade. In Canada alone, over 120 000 tonnes of electronic waste was collected for the 2011/2012 fiscal year (Electronic Product Stewardship, 2013). In the meantime, the province of Ontario, that is often considered as a main hub for major business offices in Canada, has reportedly collected and disposed of 73 103 tonnes of WEEE in 2012 (Electronic Product Stewardship, 2013). To put this number in perspective, it is important to imagine the quantity of electronic waste that is not covered by the above estimations. According to the Households and the

Environment Survey in 2011, 46% of Canadians reported to having electronic waste that they needed to dispose of (Statistics Canada, 2011). At the same time it appears that only 52% of respondents chose to get rid of their electronic through the 'formal' disposal methods (i.e. by returning them to the manufacturer or dropping them off at the designated waste collection centre). The rest of the electronics were either thrown out as garbage, donated, given away, repaired, sold or most commonly (in 26% of the cases) kept at home (Statistics Canada, 2011). This distribution suggests that a large quantity of WEEE is not being collected and accounted for in official policy and planning. It is likely that similar scenarios are common in other urban areas in the world. While the quantity of reported electronic waste is rising worldwide (with EU estimates predicting 12.3 million tonnes of e-waste in 2020) (United Nations University, 2007), a significant portion of e-waste can be unreported. Thus, although the current electronic waste diversion numbers may look very promising, they are not necessarily representative of the actual amount of electronic waste that requires active management. Consequently, the vast amounts of accounted and non-accounted electronic waste present an obvious problem for environmental sustainability.

There are many environmental issues associated with waste management in general. Over time, the variety of side effects associated with the presence of waste has molded waste management into an essential service. The provision and maintenance of safe sanitary conditions, and waste management, is listed as one of the millennium development goals (U.N.D.P, 2005; U.N.D.P, 2013). Most pressing concerns associated with waste are sanitary issues and the environmental effects related to waste disposal. The composition of waste and its potential to leach toxic, allergenic and infectious substances into the surrounding environments, as well as the risk factors associated with handling, processing and disposal of waste, are some of the top concerns relevant to waste production and disposal (Wilson et al, 2006). While electronic waste management shares many of its environmentally degrading side effects with solid waste management, it presents many further concerns of its own.

The hazardous content of the electronics themselves serves as a primary reasons for concern. Electronics are comprised of hazardous material including lead, mercury, cadmium etc, as well as non-hazardous components like gold. This composition has yielded a number of debates within the electronic production and disposal industries and rightly so, as some of the substances can be quite detrimental to human health. For example, an average computer motherboard is 1.5% lead (Huisman, 2003). High levels of lead exposure can result in lead poisoning, which may be fatal. Lead can be dangerous at low levels of exposure as well. Consistent exposure to low levels of lead may have an effect on children's intellectual development (Health Canada, 2013). Exposure to lead has been commonly tied to environmental exposure from dust, soil and water. Therefore, leaching of lead into the environment has been a common cause for concern in communities. Similar, serious health effects, including some carcinogenic properties have been associated with exposure to other hazardous components of electronics (Health Canada, 2008; Health Canada, 2008b). Thus, both electronic production and disposal (via landfilling, reuse or recycling) should be subjected to necessary safety measures in order to reduce exposure risks.

Most larger-scale electronic recycling facilities are equipped with hi-tech machinery and conveyor belts which are capable of mechanically separating, shredding and sorting the different types of material (Hageluken, 2006). This type of recycling is arguably more efficient at processing the scrapped electronics from the environmental and economic (see the Economic Sustainability section) viewpoint. This processing method has many advantages. The precious resources that are contained within electronics find themselves separated, shredded and ready for sale and incorporation into the production of new materials (Manhart, 2011). Nonetheless, there are some technical limitations to the mechanical capacity of machines. Mechanical shredding, occurring at very high speeds, often is unable to retrieve all of the many small, interwoven materials contained within WEEE. In fact, total mechanical system yield is often estimated at delivering only around 70% of precious metal content, thus losing the rest to the mechanical process (Hageluken, 2006). Cross-contamination with other materials that were not separated during the sorting stage often yields lower grade materials that then struggle to find themselves back into the production stage. The direct side-effect, of mechanical recycling's shortcomings, is the need for continuous natural resource extraction to complement the recycling process's inability to supply the necessary quantity and quality of metals.

Metals and other precious minerals represent a large proportion of the materials used to produce electrical and electronic devices (Hageluken, 2006). A personal computer's motherboard, for example, is approximately 20% copper, 7% iron, 5% aluminum, 3% tin, 1% nickel and contains trace amounts of precious metals like gold, silver and palladium (Huisman, 2003). These resources are always required to meet the demands of electronic production. The most common way to obtain metals and precious minerals is through mining. Resource extraction has been a source for continuous controversy due the historically questionable environmental and social consequences associated with mining. Some of the problems affiliated with mining include; landscape erosion and degradation; contamination of the surrounding areas with the materials used during extraction (some of which can be extremely hazardous, like cyanide used in gold leaching), and irreversible modification of an ecosystem that was once present on the site (Salomons, 1995; Malm, 1998; Nordstrom and Alpers, 1999). The extent of the many arguments tied to mining are beyond the scope of this project. However, it is quite clear that continuous extraction of resources to meet the ever-expanding demands for technology hardly appear to be environmentally sustainable in the long-term. As a result, many of the recycling and re-use policies have been fostered by concern for declining fossil fuels and natural resources (Scheinberg, 2011). The need for newly extracted resources can be alleviated by recycling as well as better re-use of electronic components and materials. High amounts of energy are used in the production of electronics such as computers (Williams et al, 2008). The relatively short lifespan of most electronics and their successive disposal or recycling results in an overall waste of energy (net waste energy of production) and resources. Thus, it has been suggested that the extension of a lifespan of electronics through reuse can mitigate the overall waste of energy (Williams et al, 2008; Kahhat et al, 2008). Manual disassembly and refurbishing of electronic devices, may prove to be a better alternative for preserving precious material components (Manhart, 2011).

A large portion of electronic re-use and refurbishing efforts occur within the informal recycling sector. More than a century ago most recycling efforts, even in the countries that are currently regarded as industrialized, were run by the informal sector. With time, many Western countries were able to get rid of the majority of the informal recyclers whose habits appeared 'non-modern' in countries striving for modernity (Scheinberg, 2011; Velis et al, 2012). The informal sector is still actively present in many developing countries. In fact, the recycling rates of the informal sector have been estimated to provide around 30%

to 50% diversion rate worldwide (Wilson et al, 2009; Scheinberg, 2011). In a number of developing countries where waste collection is unable to keep-up with demands, the informal waste sector ensures proper recycling and diversion of materials from landfill. In Karachi, Pakistan, the different groups of informal waste pickers and collectors were responsible for a recycling rate of 45% in a 1993 study (Wilson et al, 2009; Ali, 1997). In the meantime a recycling rate as high as 60% was achieved by over 300 000 informal recyclers living and working in New Dehli (Wilson et al, 2009; BKMAM, 2007). The informal sector also shows a certain talent for finding uses for a variety of discarded items that would, or in some cases, already have been landfilled (Wilson et al, 2009). Scavenging for recyclable materials like glass bottles and cans is a common activity in many urban areas even in developed countries. Vancouver 'binners' were shown to contribute to the effective reuse of a number of recyclables by extracting them from waste bins and bringing them to the collection depots, thus extending their use (Tremblay et al, 2010). This type of scavenging behaviour holds true for electrical and electronic equipment as well. In a number of developing countries second-hand computers are refurbished and used by individuals that otherwise would not be able to afford a new computer (Streicher-Porte et al, 2009). The electronics and their parts are thus re-used instead of being destroyed. This behaviour keeps the equipment within the metabolic system of the city and its surroundings, thus more closely mirroring the 'ideal' image of a sustainable city. However, despite the definite benefits of the informal sector to the waste diversion, recycling and re-use rates, there are some concerns regarding the externalities associated with the informal waste management practices.

It appears that the informality associated with the execution of the aforementioned waste management practices acts both as a positive and negative trait. The downside to the lack of organization in the informal recycling sector and small-scale re-use is expressed through its direct effects on the health of its participants and the surrounding environment. There are many occupational risks associated with re-use and recycling of waste in general. However, many informal recyclers have demonstrated a certain level of negligence towards proper safety procedures (Wilson et al, 2009). Manual waste sorting at a landfill site could have serious side effects on its participants. A study conducted in Mexico city reported an average 39 year shorter life span for dumpsite scavengers (Medina, 2000). Some of the symptoms linked to the sub-optimal sanitary conditions in which scavenging activities occur include: infections, skin disease, severe intestinal problems, physical injuries from sharp objects, chronic backache, and pains (Eerd, 1996). Although the reuse and recycling of electronics may appear to have fewer dangers than regular garbage scavenging, that is not the case. The previously discussed hazardous materials contained in electronic devices require special safety procedures and equipment. Unfortunately, improper management of electronic waste has already left its mark in certain places. In India, and a few other developing countries, uncontrolled emission of hazardous e-waste components results in air, water and soil pollution. The hazardous fumes associated with primitive recycling techniques affect the health of both the environment and people in the surrounding areas (Wath et al, 2010). An in depth analysis of the gold recovery processes from printed wiring boards in Bangalore provided insight into the gravity of dangers associated with some informal recycling (Keller, 2006). Waste solutions containing cyanide, and other acidic chemicals, were poured directly into the drain which ended in the nearest body of water.

The leftover electronic components were often deposited directly into the environment and sometimes found their way into the waste stream (Keller, 2006). Although more evidence is required to draw concrete conclusions on the environmental effects associated with e-waste recycling, the gravity of the situation remains clear. At the same time, it is important to understand that the case of electronic waste management and recycling is extremely complex. While some evidence may point to the problems associated with informal recycling, other may demonstrate its potential for improvement.

Based on the above review of the multitude of environmental factors associated with electronic waste management, it is clear that the path to environmental sustainability is quite obscure. There appears to be a strong disconnect between the theoretical image of sustainability and its practice. One apparent factor is the current system's divergence from the 'ideal metabolism' of a sustainable city. Currently, the environmental footprint of electronic waste management and production extends beyond the territory of any city. The natural resource extraction associated with the provision of materials that are required for electronic production usually occurs far away from the city limits. Industrial recycling of electronics shows potential for substituting the naturally sourced minerals with recycled ones. However, even top of the line processing technologies still do not meet the requirements for the quantity and quality of materials required for production. The re-use and refurbishing sectors have a demonstrated ability to mitigate the overall waste of energy and resources by extending the lifespan of electronics. Meanwhile there is evidence to suggest that informal recycling, even with the intention of re-use, can cause harm to the health of the workers and the environment. Such multitude of contrasting factors does appear to complicate the goal of sustainable electronic waste management. Yet, while the goal may seem distant, it is not completely unattainable. Steps can be taken to contribute to the development of a successful ‘cyclical metabolism’ in urban areas. It seems that each individual set of ‘actors` (all the various recyclers, refurbishers, informal scavengers etc.) do have a set of positive and negative characteristics. Perhaps an approach to alleviate the dependence on natural resources, and keep waste within the limits of the city and its surrounding area, would be to combine the efforts of the manual, informal re-use and large-scale recycling within the urban area itself. In fact, this scenario may not only address some of the barriers to achieving environmental sustainability but also have some economic benefit to the urban area as well. In many cases, it is the economic factors that act as a stronger motivator for change.

2.5 Economic sustainability of electronic waste management

Sustainability, in economic terms, means the maintenance of capital (i.e. the materials that are necessary to further the creation of wealth) (Mayhew, 2009; Scott and Marshall, 2009). Ideally, sustainable electronic waste management should leave the capital in the same or better state for the future generations. Economic sustainability can thus be interpreted as the preservation of the resources that enable the economy to function (Goodland and Daly, 1996). The resources involved in electronic waste management include: natural resources, energy and technology used for the production of electronics as well as the cost of activities associated with the collection and processing of electronic waste. As expected, maintaining the economic efficiency of the above activities can be quite challenging. Currently, there are many debates surrounding the 'best' economically sustainable approach to electronic waste management. The approaches range from purely government run initiatives to the informal recycling activities imbedded within the free-market. This section will outline the diverse strategies associated with electronic waste management, their economic effects, and their interrelationship with social sustainability.

There are many costs associated with electronic and electrical equipment. Even though production costs do not seem to directly apply to the discourse of electronic waste management, they are definitely relevant to the discussion of a sustainable closed-loop management system of electronics. As mentioned in previous sections, an ideal management strategy would decrease our reliance on the extraction of raw materials by re-using the already created materials. Such management will better adhere to the closed-loop system of sustainable urban development (Kennedy et al, 2007; Girardet, 2008). In fact, many government initiatives, including those of the European Union, actively promote a similar system through Extended Producer Responsibility (EPR) (Ongondo et al, 2011). EPR initiatives essentially require the original equipment manufacturers to take back their products upon disposal and recycle them in an environmentally sustainable manner. This model is commonly in place in many European countries as they are expected to adhere to the WEEE Directive instituted in the EU (European Union, 2003). In theory, this type of management leaves the majority of the responsibilities and costs of disposal with the producer. Taking on additional disposal responsibility may further improve the environmental performance of production as well. If functioning properly, EPR may encourage further equipment re-use by the original manufacturers, thus extending the life of the electronic devices. In case of some electronics, like computers, the energy required to produce a single unit far outweighs the energy used during a computer's lifetime, thus deeming direct-disposal without re-use of a computer or computer parts, highly wasteful (both with regards to energy and expense associated with its production) (Williams et al, 2008). Therefore, producer take-back and re-use of electronics acts a necessary step towards the maintenance of economic capital. However, in many cases the original product manufacturers are situated outside of the municipality's or country's boundaries. Tracing the responsible producer for equipment disposal may prove to be challenging and costly in our current trans-boundary society.

The non-localized supply of electronic equipment, in most countries, further complicates the direct take-back of electronics by the original manufacturers. A question of ownership arises as a result of the multi-faceted source of manufacturing. To address this issue, product stewardship programs have been created in a few countries and regions to oversee the proper disposal of electronics on a more local level (Ongongo et al, 2011). Product stewardship initiatives are currently in place in a number of Canadian provinces. In this type of management system the cost of collection and disposal is shared between the government, producers, distributors and consumers (Ongongo et al, 2011). [3] Nonetheless, when analyzed individually, formal collection and disposal management can prove to be very costly. If recovery rates of electronics are low, operating costs of formal collection can be very high per tonne for the municipality (Scheinberg, 2011). As a result, many locally managed waste collection and stewardship programs limit their intake of waste electronic equipment to the more eco-efficient items. The list of acceptable items for these types of

[3] The reality of cost distribution will be addressed in more detail in the results Chapters.

programs is often limited to items with a high content of precious materials and metals, such as computers, phones and other IT equipment. Otherwise, material recovery is considered economically inefficient (Manhart, 2011).

The concern with the economic efficiency of electronic disposal is tied to the high costs associated with large-scale recycling of electronics. High-efficiency electronic recycling requires high-tech equipment and thus a significant monetary investment (Manhart, 2011). Since the profit is mainly derived from the precious minerals and metals that are priced highly on the market, it is beneficial for any large-scale processor to concentrate their efforts on the electronics, which yield high amounts of desirable materials. It is important to point out that the most common way to calculate the 'desirability' of the electronic item is by the weight fraction of its precious components (Hagelüken, 2006). Items with lower valuable weight content, and often higher plastic content, (i.e. any small miscellaneous equipment and household equipment) are not prioritized for large-scale disposal. In fact, small miscellaneous electronic items and the majority of household equipment are rarely included in formal waste collection initiatives around the world (Darby and Obara, 2005). Such discrimination towards a certain type of electronic equipment, even though necessary for the economic feasibility of large-scale recycling, does not appear to meet the environmental sustainability aspects of electronic waste disposal. As a consequence, there has been a push towards merging the manual, less – formalized recycling activities with the formal waste management system (Baud et al, 2001; Hagelüken, 2006).

Manual recycling, often associated with the informal recycling sector, has many economic benefits that could contribute to electronic waste management. As previously mentioned, in the Environmental Sustainability section, mechanical recycling is limited in its ability to recover precious materials. The small quantities of precious materials may get mixed with contaminants during the mechanical separation process. While the precious minerals represent a small portion of the electronics by weight, they add up to a relatively high monetary value due to their high market value (Hagelüken, 2006). For example, the 15 ppm of gold present in a DVD-player may account for 37% of the value of the total recoverable materials (Huisman, 2003; Hagelüken, 2006). As a result, any loss of precious material will drastically decrease the total profit from the recycled item. The slower pace and more precise attention to detail associated with manual disassembly may in fact yield better value.

Manual disassembly, and the informal recycling sector, can contribute greatly to the economic sustainability of electronic waste management. One of its major contributions could be cost reduction. Formal waste management remains quite costly for many municipalities. Most costs associated with solid waste disposal are tied to the weight of the solid waste and the distance it needs to travel to the nearest landfill. At the same time, many electronic devices do not fall within the 'acceptable' items category and thus are still processed with the rest of the solid waste (Darby and Obara, 2005). Thus, scavenging activities and informal recycling may reduce the costs associated with waste disposal in a municipality by decreasing the sheer quantity of solid waste.

The high costs associated with natural resource extraction, and thus the production of electronics, may also be alleviated through more efficient recycling. Large-scale recycling and material processing often requires a high financial commitment and thus often receives subsidies from the local government in order to remain operational. In contrast, informal recycling is purely market driven, where the income is made from the sale of the recycled materials. Thus, the informal recycling sector does not require financial support and saves the authorities money (Velis et al, 2012). Following this logic, informal recycling sector has the potential to become the primary supplier of the necessary secondary raw material. The steady supply of recycled material could in turn promote the manufacturing of more affordable products (Wilson et al, 2006).

While contributing locally sourced, secondary raw material may curb the costs associated with electronic production, maintaining the functionality of electronics through re-use is arguably even better for the local economy (Williams et al, 2008; Kahhat et al, 2008). Many informal recyclers are skilled at adding value to the already disposed electronics. By manually selecting for reusable parts and adjusting the appearance and usability of some items they can re-supply second-hand electronics back into the market (Scheinberg, 2011). Sales of the locally reused electronics can in-turn contribute to the local economy. The above point demonstrates the important role that second-hand markets play in re-use of electronics. While their role is more prominent in the developing world, according to recent statistics, 16% of computers in the United States have been purchased second-hand (Williams et al, 2008; Dyrwal et al, 2000). This signifies the economic importance of re-use for both individuals and their communities. While contributing to local economic growth electronic recycling has a strong potential to address the social aspects of urban sustainability.

The economic aspects of electronic recycling and re-use have strong ties to social sustainability as well. Recycling and re-use of solid waste, including electronics, has been demonstrated to serve as an important source of income generation. The informal waste recycling practices have been shown to act as a poverty alleviation tool for a number of cities in the developing and developed world (Gutberlet, 2012). In places where other sources of income are lacking, scavenging and recycling activities have the means of providing almost immediate income to its participants. These activities contribute to both the human-made (financial) capital as well as the human (social) capital, locally.

The electronic waste management sector's contribution to the maintenance of financial capital can be calculated through the net benefit from the locally sourced secondary materials, cost of waste disposal, contributions to the local economy from the supply of second-hand electronics and individual income from engaging in recycling and re-use activities. Formal electronic waste management initiatives, run by municipalities, remain very costly. Meanwhile, extended producer responsibly is not fully capable of providing the ideal closed-loop management of electronics. Thus, third party processor involvement remains necessary to ensure that electronic recycling and re-use efforts are in fact economically feasible. While mechanical, large – scale recycling is likely capable of providing some secondary resource material, its process losses are wasting a large portion of the highly valuable precious materials. Manual disassembly may be a useful addition to compliment the already existing mechanical recycling sector. It can also directly support the local financial and social capital. In the end, combining the efforts of the larger-scale recycling and the manual, informal sector appears necessary to ensure economic efficiency of electronic waste management. Unfortunately, while some municipalities are recognizing the positive economic side - effects of informal recycling practices, a negative social perspective is still associated with the informal recycling initiatives worldwide. It is important to note however, that the informal sector is not without its negative attributes either.

2.6 Social sustainability of electronic waste management

Out of the three pillars of sustainability, social sustainability is perhaps the easiest to observe on a local level. Despite this, the social pillar remains the most complex to define. Conversations regarding social sustainability are exceedingly large in scope and involve topics like social equity, social coherence (Dempsey et al, 2011), sustainable communities (O.D.P.M., 2006) and sustainable livelihoods (Hopwood et al, 2005). While disagreements remain between the priority of each individual pillar of sustainability over the other (e.g. economic development over environmental conservation), the same can be said for the multitude of debates between the different goals of a socially sustainable community. As a consequence, while the shadows of social inequality are apparent in real life, it is difficult to determine what the sustainable alternative would resemble. In the case of waste management, the social sustainability debate is exceptionally bipolar. The main argument revolves around the existence of the informal recycling sector. While informal recycling activities provide a critical source of income in some situations, they can also be harmful to the health of its participants and the surrounding environment. This section will review the two sides of the debate. It will focus on comparing the theoretical goals of social sustainability to those that are practically feasible, thus outlining the difficulty that such broad concept faces upon translation into reality.

Indeed there are a number of health and environmental concerns associated with electronic recycling and specifically informal electronic recycling. As mentioned in the Environmental Sustainability section, the hazardous materials contained within electronic and electrical devices require precaution upon disassembly. Mechanical, large-scale recycling facilities generally prioritize the safety of their employees, in accordance with their region's health and safety regulations (Manhart, 2011). Although one must keep in mind that these regulations vary from region to region, and thus may not be deemed equally safe by all. Nonetheless, while large-scale processors often meet some manner of worker's safety requirement, the same cannot be said for the informal style of recycling.

Historically, informal recyclers have been associated with unhygienic working conditions (Scheinberg et al, 2011). There have been disturbing reports of health side effects from informal recycling and associated environmental contamination. High blood lead levels, exceeding the concern level of 10 ug/dL designated by the U.S. Centre for Disease Control and Prevention, were found in children who have come into regular contact with electronic waste in Guiyu, China (Huo et al, 2007; Williams et al, 2008). Unsafe disposal and disassembly procedures have been observed at a number of informal recycling sites. In Banglore, workers were reported to wear no safety equipment, such as gloves, masks or goggles, while dealing with cyanide solutions, used for gold leaching from printed wiring boards. Cyanide is a highly dangerous and potentially lethal compound. Lethal oral doses of cyanide range from 50 to 200 mg, with death occurring within one hour of exposure (Health Canada, 2008). Many workers were reported to have burn marks and severe skin discolouration as side effect of contact with acidic substances (Keller, 2006). Such obvious disregard for basic safety does in fact paint a negative image of informal electronic recycling. Workplace safety is a basic social right that should not be ignored. Theoretically it appears reasonable to disallow any unsafe recycling practices to ensure human safety. Nonetheless, it is important to recognize the complexity of the social sustainability argument within waste management, and in particular the benefits that informal work may provide (Wilson et al, 2006).

Manual activities associated with waste management are labour intensive and thus have the potential to create a high number of employment opportunities (Gutberlet, 2012). Processing of recyclables could provide 10 times more jobs than landfilling and incineration of solid waste (Gutbertlet, 2012). This potential is crucial to the areas of the world where employment is difficult to obtain. According to recent statistics, nearly 2% of the population in developing countries is involved in the informal recycling sector (Gutberlet, 2012; Medina, 2000). Informal recycling is not completely absent from developed urban centres either. Extraction of valuable recyclables, like glass bottles and aluminum cans, (i.e. 'binning') was demonstrated to aid poverty reduction in the City of Vancouver, Canada (Gutberlet, 2009). Similar scavenging activities for electronic waste may yield an even higher income due to the high material costs and demands for electronics in urban centres (Lepawsky and Billah, 2011). In fact, informal recyclers are capable of creating a market for second-hand goods in a whole variety of places. On Bangladeshi shores, materials collected by scavengers during ship disassembly, contribute to the economic development of the area (Gregson et al, 2010). Engaging in an activity like informal recycling can be the difference between survival and starvation for some (Wilson et al, 2006). Manual disassembly involves a number of different activities, each varying in its requirements for physical and technical skills. Consequently, this type of employment may be accessible to a variety of workers, including women and people with disabilities (Gutberlet, 2012; Community Living Guelph and Wellington, 2013). Nonetheless, special priority should be given to ensuring that these activities provide social and economic benefit to the local population without harming their health.

It has been suggested that creating partnerships between informal recycling efforts and the more formalized waste management system may be the most socially, environmentally and economically sustainable solution (Baud et al, 2001). Organizing individual recyclers into co-operatives or small-scale, local businesses may encourage government's recognition of their efforts (Parizeau, 2013; Gutberlet, 2012; Velis et al, 2012). Building active relationships between the informal recycling sector and the local government may be beneficial to both parties. An organized group of recyclers is more likely to participate and be included in the democratic process and decisions regarding local waste management (Velis et al, 2012). In order to sustain or promote their legal standing they may better adhere to environmental and health standards associated with their work (Gutberlet, 2012). In turn, the local government may benefit financially by reducing its spending on waste collection and disposal. Participation in local social processes may encourage the creation of stronger bonds, and thus better 'social cohesion', between local recycling organization and the government. [4]A community that demonstrates high social cohesion is arguably more sustainable, since the existence of many interactions between residents results in higher resilience (Dempsey et al, 2011; Prell, 2011). Such collaboration has brought many benefits to several urban areas (Streicher – Porte et al, 2009). A local organization, *Computadores para Educar*, has been supplying locally refurbished computers to a large number of public-run schools in Colombia. As of 2008, the organization has supplied over three million computers to local schools. Similar public-private partnerships, often varying greatly in scale, exist in other locations. In Kenya, an organization titled "Computers for

[4] The term 'social cohesion' refers to the availability of close relationships within a community.

schools Kenya", has been supplying low-cost IT equipment to education centres locally (Streicher – Porte et al, 2009). Most importantly, if allowed to flourish, these type of small and large-scale refurbishing and recycling efforts could greatly contribute to another aspect of social sustainability associated with waste management of electronics – the reduction of the 'digital divide' worldwide.

The gap between the portion of the world's population that has access to digital communication and those without it, has been called the 'digital divide' (Streicher – Porte et al, 2008). Better access to technology can benefit the development of a community. In particular, youth computer literacy may have great benefits to the economy in the long term. Additionally, the communication aspect of digital technologies may add to the 'social cohesion' part of social sustainability (Wellman, 2001). While the 'gap' is often imagined to be the largest between the global North and South, the 'divide' is not completely absent from the urban centres of the developed world themselves (DiMaggio et al, 2001). Nowadays, lack of access to technology limits personal access to information, education and even livelihood, by restricting access to job searches (Anderson et al, 1995). New electronic devices are becoming cheaper, however, they are still largely unaffordable to the lower-income portion of the population. Computer re-use and refurbishing can contribute to the reduction of the 'digital divide' in many communities.

There are many participants in the electronic waste management sector. Each of them contributes differently to ensuring an equal social benefit from the production, use and disposal of electronics. However, while strong relationships are often present in urban communities between the local government and large-scale processors, the informal and small-scale recycling and re-use efforts are often unrecognized (Baud et al, 2001; Gutberlet, 2009, Gutberlet, 2020, Wilson et al, 2009 among others). In fact, informal recycling is often faced with negative reception from the local government and community. Informal recycling is commonly perceived as a barrier to 'modernization' (Scheinberg, 2011).

One of the common goals of waste management in the developing world is to move up the 'waste hierarchy' (Wilson et al, 2006). Not so long ago, informal recycling and scavenging dominated the waste management sector in what are now considered industrialized countries (Velis et al, 2012; O'Brien, 2008; Gille, 2007). Over time though, the western capitalist system played a role in altering the attitude towards waste management. Informal waste collection was deemed inefficient and the more formalized, widespread waste collection and disposal system, that we are currently familiar with, became predominant in industrialized countries. The immediate side effect of this development was the changing perspective towards any informal recycling efforts. Non – western countries' strive towards modernity, often associated with the practices adopted in industrialized countries, has arguably played a role in many infrastructure efforts, including waste management. The formalization of the waste management sector in the developed world had its effects on the developing countries. As result, informal recycling became regarded as a 'dirty', and un-modern activity (Velis et al, 2012). This perspective is ironic considering the previously mentioned environmental and economic benefits (Section 2.3 and Section 2.4) that informal recycling provides in areas where waste is not even collected by the municipalities. Many municipalities, in both the developed and developing countries, have become quiet preoccupied with the elimination of informal recyclers all together. Criminalization of waste picking is not uncommon in urban centres (Sembiring and Nitivattananon, 2010; Scheinberg, 2011). In other cases, local government has attempted indirect displacement of the informal sector, via the privatization of waste collection (Wilson et al, 2009). The negative attitude towards informal recycling efforts, despite its historically prominent role in waste diversion, can be tied to our political regime's strive towards modernity and growth.

Historically, 'growth' has been incorrectly perceived as a solution to many global problems, including social inequality (Marcuse, 1998; Hopwood et al, 2005). Contrary to their initial intention, however, government's concentrated efforts on 'growth' and 'modernity' have resulted in the expansion of the gap between the poor and the wealthy. Thus, creating a more modern waste management system, while perhaps alleviating some environmental effects of waste disposal, will not address the issues of poverty (Velis et al, 2012). Criminalizing informal recycling activities will render the ongoing social and economic abuse towards its participants acceptable. Currently, active discrimination against the urban poor represented within the informal sector is only intensifying the barrier between our current society and the theoretical image of an equitable society where no discriminatory practices occur. To address these issues, some governmental and non-governmental groups have been promoting the recognition of informal recycling efforts and their inclusion in the formal waste management sector (Gutberlet, 2012; Velis et al, 2012). It can thus be argued that the creation of stronger coalitions between the informal and small-scale recyclers, their large-scale, formalized counterparts and the local government could aid in the creation of a successful sustainable waste management system (Baud et al, 2001; Gutberlet, 2012; Wilson et al, 2009; Velis et al, 2012; Scheinberg, 2011).

Overall, it seems that manual disassembly efforts and informal recycling sector can largely contribute to the development of a socially sustainable community. As long as the dangerous health and environmental side effects are addressed, electronic waste management has the potential to provide a necessary source of employment as well as decrease the 'digital divide'. On the other hand, practices that intentionally criminalize the livelihood of a large portion of the population in the developed and developing urban centres, can hardly meet the criteria of sustainable development. While keeping in accordance with the ideals of sustainability, all types of waste management sectors should be treated equally. Following this logic, an all-inclusive waste management system could address the multitude of social (poverty, health effects and digital divide), environmental (environmental contamination) and economic (resource extraction, recycling and production costs) issues associated with waste management.

2.7 Sustainability of electronic waste management

The above sections provided an in-depth review into the meaning and application of the concept of sustainability. The practical application of sustainability ideas has shown greater potential on the local scale of individual communities and cities. Participation of community members has been highlighted as an essential aspect of sustainable urban development. In turn, the successful creation and maintenance of a sustainable city has been shown to depend on the city's ability to achieve self-sufficiency and provide social equality to all of its residents. The above essential components of urban sustainability are embodied within sustainable waste management. While waste management has a direct effect on the maintenance of resources within the city, it also has the potential to provide a number of social benefits.

The importance of waste management, and electronic waste management in particular, to the achievement of local and global sustainability are demonstrated in the above review. It has been argued that the promotion of alliances between the formal, large-scale processors; small-scale, manual recycling and, the informal sectors of electronic waste management has the greatest potential to address the environmental, economic and social mandates of sustainability. The above idea describes the 'best-case' scenario towards which urban waste management should strive. Nonetheless, the detailed review of the current state of waste management worldwide has also effectively demonstrated the disconnect between the above ideal image of sustainable waste management and the reality. These kinds of inconsistencies must be addressed to promote the development of sustainable urban electronic waste management.

The analysis of the three pillars yielded several important characteristics that together could enable progress. From the environmental perspective, recycling and refurbishing of electronic waste within the urban area better adhere to the standards of 'cyclical metabolism'. Electronic waste management can better achieve economic sustainability through collaboration between mechanical recyclers and manual processors of electronic waste. This collaboration could in turn sustain the local economy and support the community through the supply of technical jobs. Finally, a more even distribution of electronic waste within local community could address the issues of the 'digital divide' and thus promote social sustainability. Yet, these goals will not likely be reached with ease. In fact, it is unclear whether the above characteristics of sustainable electronic waste management are attainable. The reality of the complexity behind the application of sustainable goals on a local and global scale needs to be understood further. Therefore, the purpose of this study is to analyze the potential to embrace the 'sustainability ideals' while managing electronic waste in a developed urban centre.

This research project explores the currently existing electronic waste management system in the Census Metropolitan Area of the City of Toronto, Ontario. Several methodologies are employed to understand the existing relationships between the major actors in the waste management network and the network's capacity to embrace sustainable waste management ideals. The results of the thorough analysis of the city's waste management system provide a more coherent understanding of the translation of 'sustainable development' ideas into the management of an urban centre.

CHAPTER 3: Data Collection and Analysis

3.1 Introduction to Methodologies

The goal of this study is to analyze the current and future sustainability of the electronic waste management sector in The City of Toronto, Ontario, Canada. According to the themes presented in the literature, a sustainable waste management system must equally address all three pillars of sustainability. The following characteristics summarize the key necessary attributes to achieving the environmental, economic and social goals of electronic waste management in an urban area, like Toronto.

- The city can better strive towards the 'ideal' image of the 'cyclical' metabolic system by halting the production of any harmful waste and their deposition outside of its boundaries and/or reusing all the waste within the urban area. The review of the literature suggests that recycling; refurbishing and reusing the discarded electronics locally can reduce environmentally harmful aspects of electronic waste management.
- The economic efficiency of electronic waste management can be achieved through collaboration between large and small-scale processors as well as manual disassembly efforts. Such diverse range of participants may curb the costs of formal waste management while adding economic benefit to the City through the creation of localized jobs.
- A more evenly distributed access to electronics and jobs in electronic recycling and refurbishing can be beneficial to local sustainability. As long as the harmful side

effects of electronic disassembly are addressed, no discriminatory practices restricting the above activities should occur in a socially sustainable urban community.

The above characteristics will be discussed in more detail in the following Chapters. Meanwhile, it is important to point out a common attribute through which the above goals can be achieved. The characteristics of sustainable waste management can be addressed through the promotion of stronger alliances between the varieties of sectors/ actors involved in waste processing. The creation of interrelationships between the formal and informal sectors in waste management has been demonstrated to result in stronger community sustainability (Baud et al, 2001; Gutberlet, 2012; Wilson et al, 2008). These findings can be further applied to electronic waste management. The promotion of strong alliances between large-scale electronic processors, small-scale entrepreneurs and even the informal sectors could act as a key characteristic in the creation of sustainable electronic waste management and thus benefit urban sustainable development. Consequently, the researcher plans to analyze the potential of the City of Toronto's community to support the above attribute. In order to complete such analysis, the existing management system in Toronto has to be thoroughly explored. In addition to that, the system's capacity to promote an inclusive waste management sector has to be analyzed. The necessary analysis is completed via multiple data collection and analysis methodologies. The methodologies are in-turn designed to address the following research questions:

1) What is the structure of the electronic waste management networks in Toronto?
    a. What is the overall structure of social alliances and material flow within the e-waste management system in Toronto?

b. What role do the various actors play in the development of a sustainable electronic waste management system?

2) How, if at all, could the sustainability of the existing electronic waste management system be enhanced?

In order to gain a comprehensive understanding of the current electronic waste management system in Toronto, multiple data collection and analysis methodologies are used throughout the duration of the research project. The methods are initially separated into those addressing the overall structure of the network, and those focused on the specific roles of each actor in the sustainability of the overall system. The necessary information required to address the first part of the research objective is obtained by completing a 'Network Analysis'. This methodology reveals the configuration of the electronic waste management networks in the city. Complementary information, specifically focusing on the sustainability of the existing waste management systems and the role of each individual actor is provided through an in-depth 'System Audit'. The combination of the multitude of methods is essential to illuminate the complex world of electronic waste management in an urban centre. The following sections will explain the data collection and data analysis methods that were used as a part of this research study.

3.2 Network Analysis

One of the main goals of the research project is to thoroughly understand the configuration of networks (relationships between actors and flow of electronic waste) within the current electronic waste management system. Such in-depth understanding can be provided through a visual depiction of the participants and their relationships within the management sector. Therefore, it is a goal of the researcher to use a coherent visual method to depict the existing waste management system in Toronto. The primary methodology used for "Network Analysis" is developed through a review of similar studies.

3.2.1 Background of Network Analysis

Much of the academic work on waste management incorporates a certain type of a visual representation of the procedures and participants involved in the system. While some visualizations serve solely for illustration purposes, others provide the possibility of in-depth quantitative analysis. For example, Wilson and colleagues (2001) use a schematic to demonstrate the flow of the solid waste in Bangkok in 1987. The visual representation (Figure 3.1) depicts the movement of the solid waste from the point of waste generation to a number of secondary and tertiary downstream processors (Wilson et al, 2006; Wilson et al; 2001; Wilson et al, 1988). The schematic serves as a great aid to understanding the general movement of solid waste and recyclables between the different parties. Similar types of illustrations can be used while describing a variety of waste management systems. Baud et al. (2001) depict the hypothetical relationships between the various participants in the waste management system in three different cities (Figure 3.2). The researchers' work demonstrates the importance of alliances within any management system. It further suggests that any illustration of waste management process should in theory depict all of the important actors involved. Nonetheless, the illustrations from the above examples are limited to their qualitative capacity. While such types of visual depictions are useful for descriptive analysis, they do not provide much opportunity for further quantitative and statistical analysis. A more systematic visual representation can be attributed to the more detailed analysis of the 'material flow' in the waste management sector.

Material flow analysis (MFA) is a common methodology used in the assessment of waste management systems (Rochat et al, 2013). The analysis depicts the relevant inputs and outputs of the materials within the system. It essentially demonstrates the movement of mass throughout the management process. It can thus be useful in improving the existing material flow towards a more 'closed-loop' resource management strategy (Gurauskiene and Stasiskiene, 2011; Brunner and Ma, 2009; Hischier et al, 2005). The analysis often yields a visual depiction of the material flow processes as well as some statistical data. MFA is often relied on in the municipal assessments of waste management. Hischier et al. (2005) use a hybrid of MFA and life cycle assessment methodology to provide an overview of the Swiss WEEE management system (Figure 3.3). The visual depiction of the electronic waste flow is accompanied by a numerical breakdown of the inputs and outputs for each contractor. Similarly, Gurauskiene and Stasiskiene (2011) use MFA while exploring the state of the electronic waste management system in Lithuania. Their particular visualization of the material flow demonstrates the potential of MFA to provide comprehensive quantitative data (Figure 3.4). These examples also illustrate the usefulness of material flow analysis in unveiling the 'metabolical' pathways of any management sector. Yet despite the many positive attributes of MFA, the lack of the social context for the more quantitative analysis is evident. As per our earlier discussion, an all-encompassing waste management system must equally prioritize its economic, environmental and social effects. Following that logic, its analysis methodology must also address the three pillars of sustainability equally.

A socially focused methodology that has been gaining popularity in academia is Social Network Analysis (SNA). This methodology provides a visual and statistical depiction of the relationships within a 'network' (municipality, city, organization, community etc.) SNA is a popular tool in academic research as well as in planning and policy. Government agencies can use SNA to insure that all of the relevant representatives (various subgroups, minorities and organizations) are in fact engaged in a participatory process (Prell et al, 2009). While conducting a study, a variety of maps can be created to depict different relationships in a network: distribution of individuals based on organizations or affiliation with a particular sector of the industry, material flow between the actors, financial flow between the organizations etc. The resulting visualization depends on the types of questions asked by the researchers during the data collection stage. Apart from the visual analysis, SNA may also involve statistical analysis. A variety of SNA software exists to assist in the statistical analysis of the data. Some of the common statistical measurement include: network density (extent to which all the individual actors in a network are linked together (how many ties exist out of the maximum)), degree centralization (extent to which one actor in a network is holding all of the ties in the network), reciprocity (proportion of observed ties that are named by both nodes) etc. (Prell, 2011). Performing these calculations better grounds some of the preliminary visual observations. Statistical analysis also has the potential to unveil some network characteristics that would otherwise be undistinguishable in a visual observation.

The flexibility of the SNA methodology has made it popular in a number of academic and non-academic settings (Prell, 2011). The use of SNA has more recently become common in natural resource management. Environmental management and conservation shares many parallels with waste management and thus can arguably also share a methodology. There are a number of important factors that promote a more sustainable management strategy. Understanding the structure of social networks is one of them. It can lead to a better cooperation between the actors involved and thus result in stronger resilience (Prell, 2011; Vance-Borland and Holley, 2011; Prell et al, 2009). This hypothesis is tested in the analysis of the networks involved in natural conservation in Lincoln County, Oregon Coast, U.S. (Vance – Borland and Holley, 2011). The visual depiction of the networks helps identify crucial relationships within the conservation sector (Fig 3.5). The map also yields better understanding of how decision-making power is allocated between individuals and organizations. Such in-depth understanding of the network activity in resource management can be crucial to its long-term functionality. Since electronic waste can be perceived as a resource, an analogy can be drawn between the methodology used by Vance-Borland and Holley (2011) and the questions investigated in my research.

To conclude, all of the above-described methodologies contain useful attributes to our analysis. In particular, Social Network Analysis provides the necessary social context. At the same time, Material Flow Analysis is able to supply supporting quantitative data. Thus, the resulting methodology for this research project is grounded in Social Network Analysis while maintaining some characteristics of Material Flow Analysis as well.

Figure 3.1 Visual representation of solid waste management system in Bankok (Wilson et al, 2006; Wilson et al, 2001)

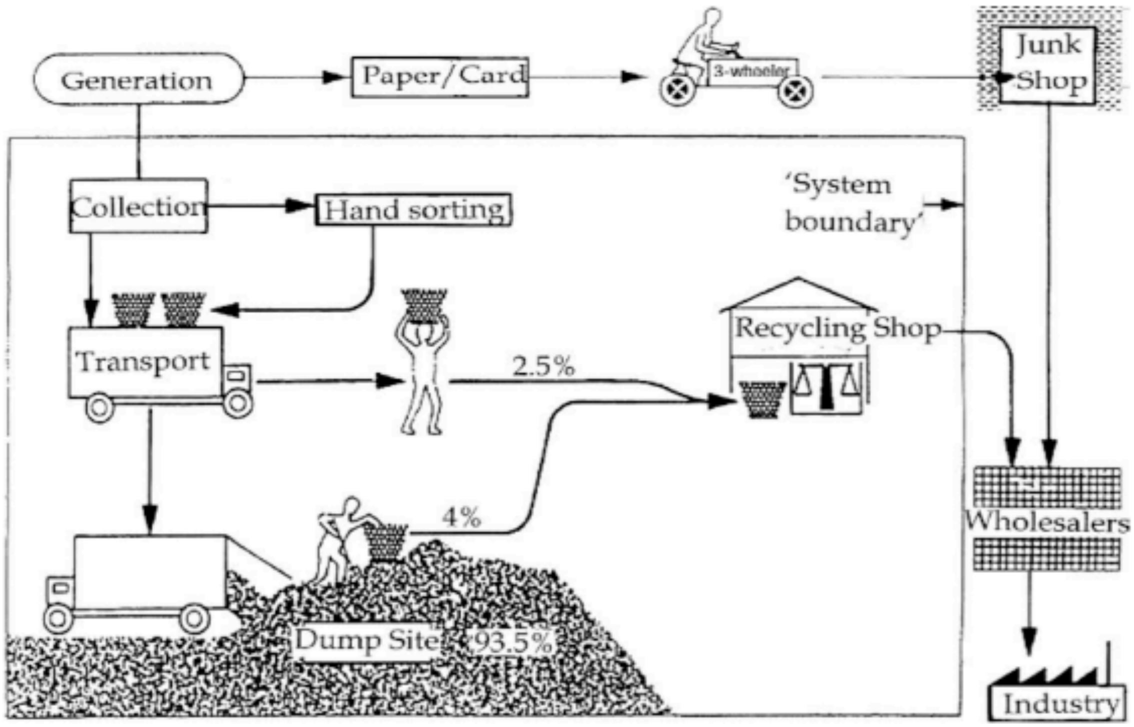


Figure 3.2 Alliances within solid waste management in an urban centre (Baud et al, 2001)

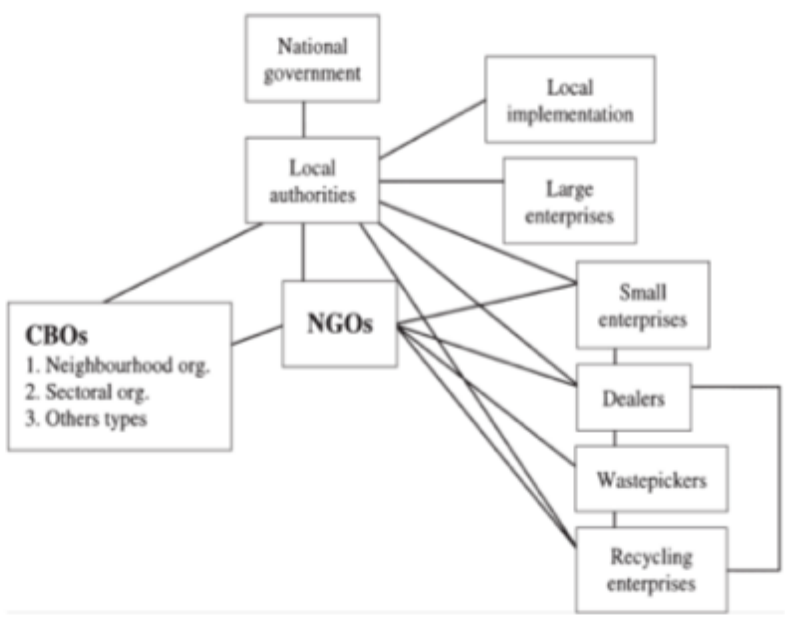


Figure 3.3 Modeled WEEE take back system (Hischier et al, 2005)

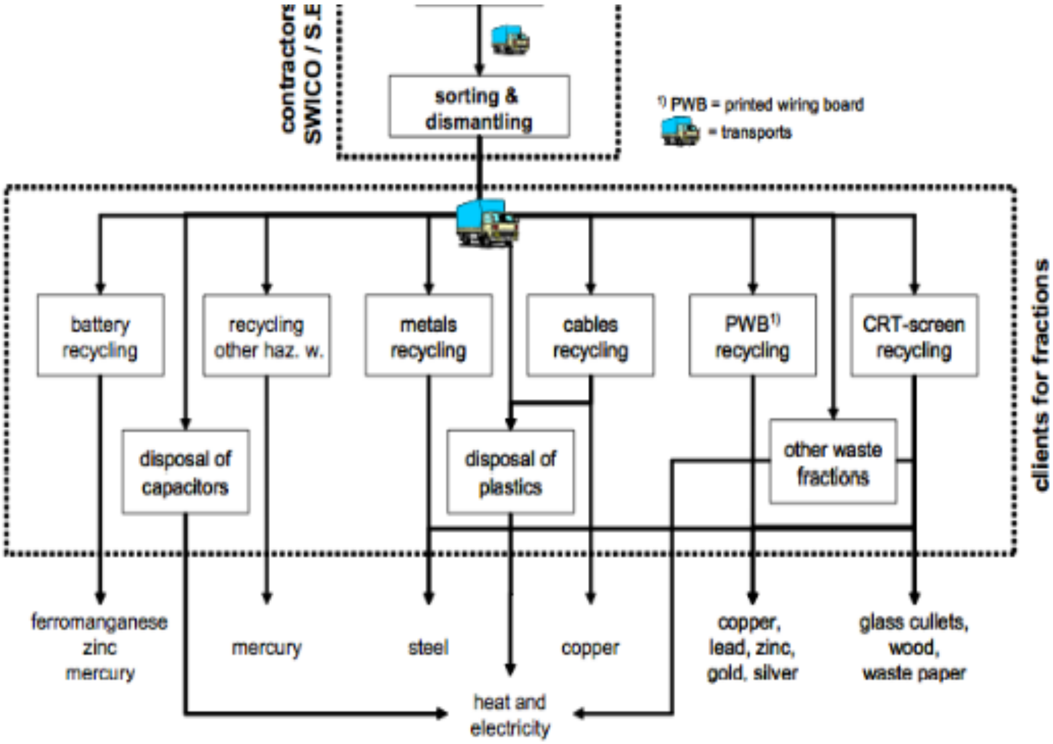


Figure 3.4 Material flow analysis for a solid waste management system (Gurauskiene and Stasiskiene, 2011)

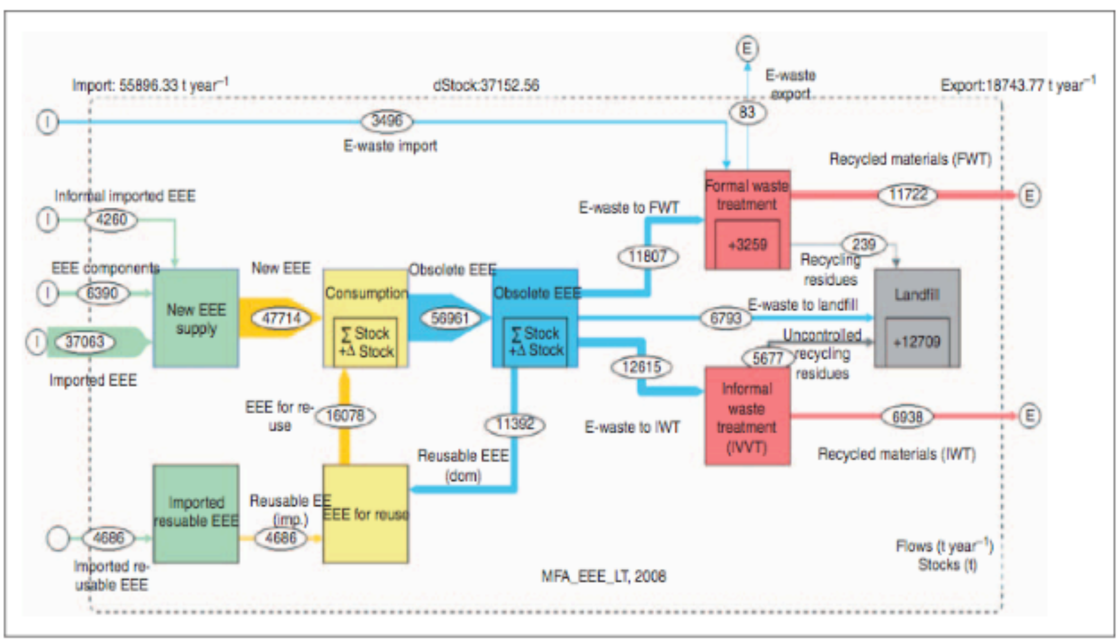
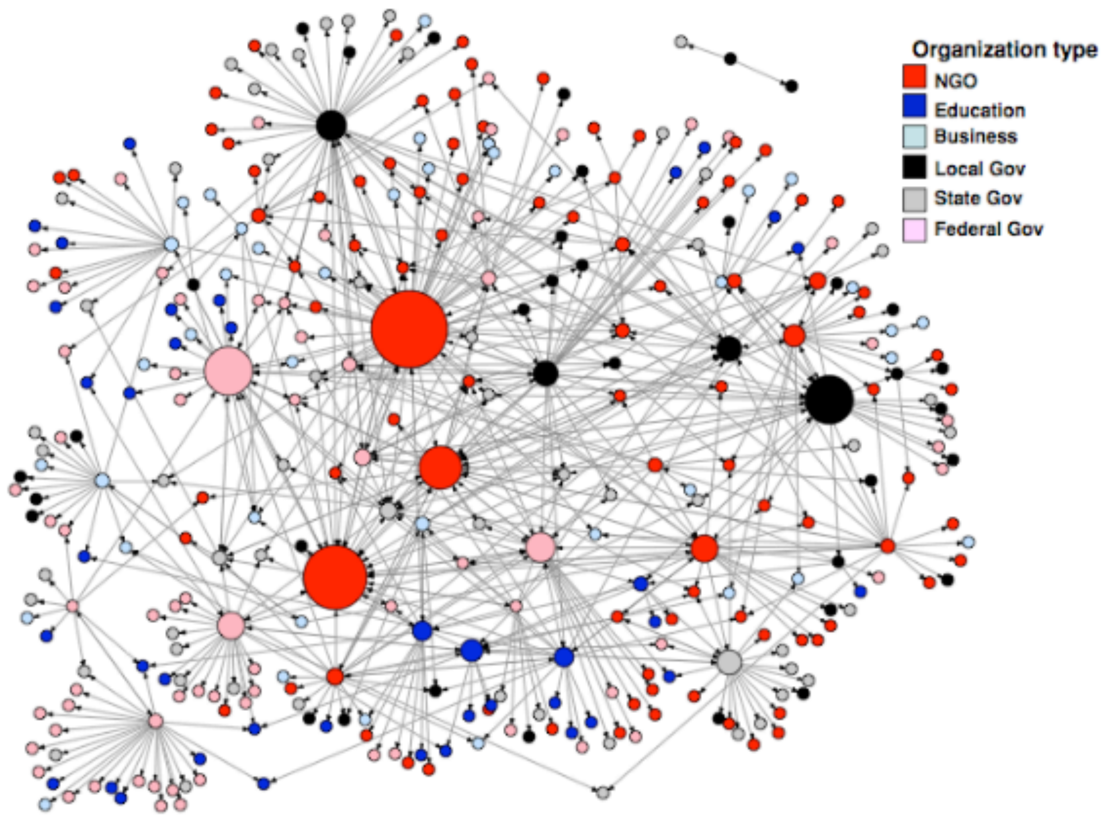


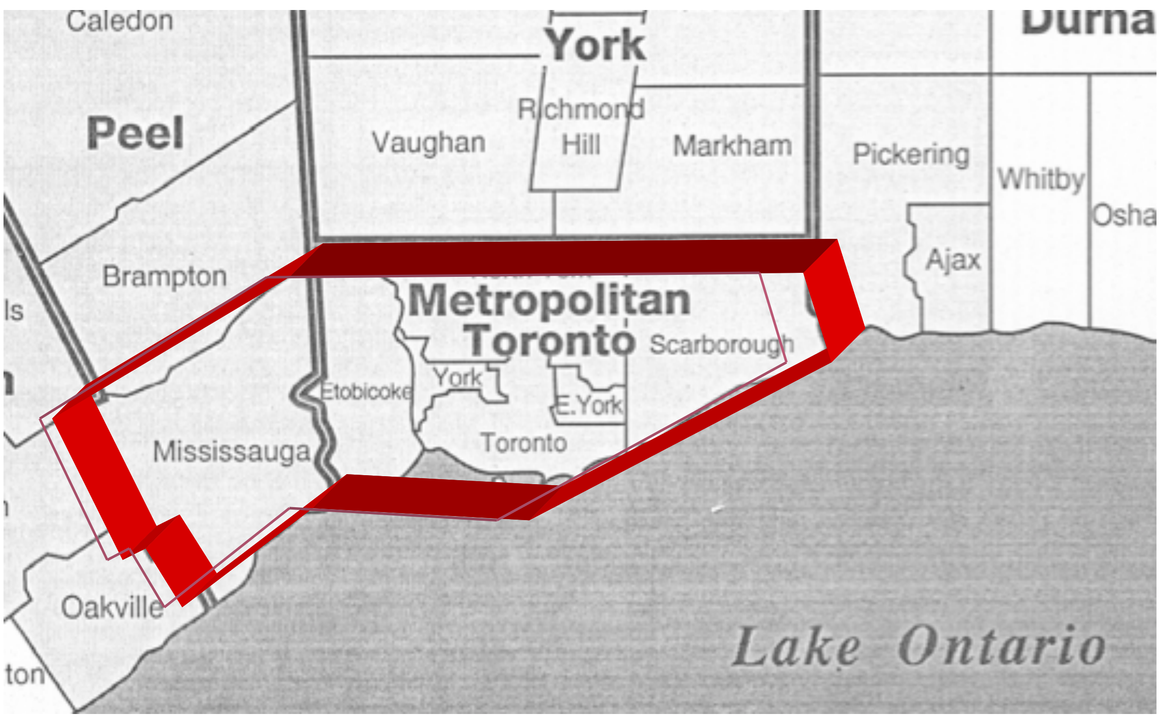
Figure 3.5 Social networks of environmental conservation (Vance-Borland and Holley, 2012)



3.2.2 Network Data Collection

The primary goal of 'Network Analysis' is to depict the existing relationships and functionality of the electronic waste management system in Toronto. In order to meet that goal, the main actors (private organizations, individuals, government organization etc.) have to be identified. Furthermore, the relationships between individual actors have to be recorded and depicted in the final network. This section will describe the step-by-step processes of data collection and analysis that occurred as a part of the 'Network Analysis' methodology.

Figure 3.6 Map of the research areas including the Census Metropolitan Area of Toronto and one adjacent area of Mississauga.



Source of original image: Metropolitan Toronto Council, 1995

As mentioned previously, the Greater Toronto Area includes the City of Toronto's electronic curbside collection, which serves over 2.5 million residents. The area is also a major hub for many Canadian and international corporations. Consequently, the quantity of electronic waste produced by the said corporations and residents requires the presence of many electronic waste processors in the same area. Due to the constraining timelines of a Master's dissertation and limitations of the sole researcher to collect information regarding all of the electronic waste management activity within the Greater Toronto Area, the actual geographic area of the research had to be reduced to the Census Metropolitan Area of Toronto as well as one adjacent area (Mississauga)[5] (Please refer to Figure 3.6). The relevant organizations (government, waste processors, collectors and refurbishers) were first researched online at the City of Toronto Waste Management and Ontario Electronic Stewardship web pages (the two relevant entities overseeing electronic waste disposal in Toronto). A total of 4 electronic waste recyclers/ processors and 6 reusers and refurbishers were found to be registered and located within the research area (OES, 2014). Internet database searches also yielded the names of 4 more recycling/ refurbishing organization, located within the area, that were not listed on the OES web-page. All of the above organizations were contacted for Network Analysis interviews. A 50% response rate (n=14) was achieved. Four of the respondents were able to provide the researcher with an in-depth site visit (see Section 3.3.1) as well as an interview. Three of the other participants chose to

[5] The original contact with one of the non-profit electronic refurbishers was established prior to the final modification of the research area. This particular refurbisher's "Toronto location" was geographically located in Mississauga (within the GTA area). Limiting the research to only CMA refurbishers would have eliminated this particular lead and resulted in data collected from the remaining single refurbisher located within the City limits. Thus, the research area was extended to include Mississauga and its electronic refurbishers and recyclers.

respond to the questionnaire via a phone-interview. Two more in-depth interviews were conducted with the two government bodies that actively participate in the management of electronic waste. A phone-interview, in-person interview and a site visit was conducted with several representatives of the City of Toronto Waste Management department. An in-person interview was conducted with the Director of Ontario Electronic Stewardship.

Typically, in Social Network Analysis, data collection begins with identifying a few key participants who then reveal other potential participants. The sampling then continues via data collection methodology such as 'snowballing' (Prell, 2011). Initially, the data collection methodology for my 'Network Analysis' was supposed to primarily rely on the Network Analysis Questionnaire. The Questionnaire was designed by closely mirroring the questions used in the Vance-Borland and Holley study (2011). A mixture of quantitative and qualitative questions was included in order to address the 'material flow' and 'social network analysis' aspects of the research. The questionnaire (please see Appendix I) was expected to reveal future potential participants. Upon the completion of the first few interviews, however, it became apparent that the participants were hesitant to disclose the actual names of their contacts (other actors in the network). While some of the interviewees identified a few main actors, others preferred to refer to other individuals and companies by their general descriptors (i.e. downstream metal recycler, junk collectors, other electronic processors etc). It is likely that competitive nature of the e-waste market can be linked to the hesitation with which this information was revealed by some organizations. Inevitably, it became rather difficult to follow-up on these descriptors with interviews, as a traditional SNA methodology would require. This obstacle resulted in the modification of the initial data collection methods. The researcher was left to find many electronic waste processors/

collectors/ refurbishers by herself. Consequently, most potential participants were located online and then contacted by phone or through e-mail.

The above modification of data collection methodology additionally limited the interpretation of the alliances between individual people and instead was more useful in explaining the relationships between whole organizations. While the substitution of whole organizations for individual actors is not unheard of in Social Network Analysis, this additional circumstance modified the statistical analysis capacity of the final network. At the same time, most of the participants were able to share the detailed quantitative information concerning their organization's inputs and outputs. As a result, the researcher was able to use an amalgamation of data from the actual questionnaires as well as the quantitative and qualitative data revealed during interviews for the final compilation of the electronic waste management networks.

3.2.3 Network Data Analysis and Limitations

Research data was compiled and analyzed with the help of Social Network Analysis software: Gephi. An individual Gephi file was created for each participant/ actor in the electronic waste management network. Upon the completion of each Network Analysis Questionnaire; the data were entered into the Gephi file. The parameters entered into each file included: actors (the names of organization or assigned identifiers); each organization's inputs and outputs of material per year (in metric tonnes); the source of materials (various collectors or individual clients) and the final disposal destination (downstream processors; donations etc.). A graphic was created to portray the data collected for each individual actor. This stage of data analysis yielded 7 individual 'material flow charts' depicting the source of inputs and outputs of electronic waste for each individual electronic waste management processor.

The individual data collected during each interview was used to create three 'Network Analysis Maps'. The information depicting the relationships between various actors (i.e suppliers of electronic waste, electronic waste processors; collectors and downstream processors as well as the government offices) was combined in one Gephi file, titled the “Collaboration Network”. The names of all actors participating in electronic waste management in Toronto CMA were recorded within the file. Unidirectional relationships were recorded between the actors who either directly indicated the existence of a relationship or who were recognized as collaborators by other participants. The resulting network depicted the social interactions between actors within the electronic waste management sector.

The quantitative, material flow information for each participant was used to create a large “Material Flow Network” for the Toronto CMA. The single Network was eventually depicted through two marginally different visualizations (one focused on the identification of organization (Figure 6.3) while the other focused on the types of material flow (Figure 6.4)). The individual organizations were linked via the flow (input or output) of the electronic materials. Multidirectional relationships were displayed for each actor. The analysis yielded two “Material Network” maps of the electronic waste movement from actor to actor within Toronto. The visual appearance of the networks was modified through a variety of Gephi graphic tools. The size, colour and layout of the nodes and edges were modified for best visual appearance. The resulting network diagrams and material flow diagrams played a significant role in the final research results.

Overall, while the Network Analysis methodology may not have necessary yielded all of the anticipated data, it was able to provide a good overview of the key relationships within the network. As per the researcher's intensions, the key message from the network (the obvious absence or presence of particular types of actors and materials over the others) is strongly depicted through the visualizations. Arguably, an addition of more actors to the analysis or an expansion in the geographical scope of the study can further unveil the structural aspects of the network. These characteristics will be depicted in more detail in the Results chapters.

3.3 System Audit

The main purpose of the research project is to analyze the 'sustainability' of the existing electronic waste management system. Particular focus is paid to the system's potential to engage with representatives from the variety of sectors (large-scale; small-scale; formal; informal; non-profit etc.). In order to provide the needed information for such an analysis, a multi-methodology data collection and analysis was required. The following sub-sections will describe the various data collection and analysis methods employed by the researcher for the duration of this project.

3.3.2 Participant Observation and Site Visits

In order to truly understand the inner characteristics of the existing electronic waste management sector in Toronto, qualitative and quantitative observation are needed to complement the more visual approach to "Network Analysis". 'Insider's' perspective on electronic recycling and refurbishing is seen as a necessary attribute to the overall picture of electronic waste management in the city. Important details of the every-day experiences within a researched area can be obtained through participant observation methodology. Participant observation and site visits are thus used to provide deeper appreciations for the intrinsic characteristics of the electronic waste management sector in Toronto.

Participant observation is a methodology closely associated with the fields of sociology and anthropology. It is widely used in academia to relay the inner characteristics of the research subjects (communities, organizations, individuals etc.). It is an observational approach in which the researcher becomes immersed in the studied community (Rollinson, 2010; Schoene; 2011). Its ability to reveal the 'insider's' perspective of certain events has increased its popularity in nature conservation and resource management fields (Fabinyi et al, 2010). Participant observation is often used in combination with other methodologies. In the context of this research project, participant observation is deemed necessary to create an all-encompassing picture of the electronic waste management sector.

A large portion of the project focuses on the specific role of each type of electronic waste management sector, and its participants, within the larger network. Active involvement in the different types of every-day activities associated with electronic recycling and refurbishing is useful to the overall goals of the project. As a result, a part of the data collection process included site visits and participant observation within a number of electronic processing facilities. The researcher was able to visit six different sites: three large-scale electronic waste processors; two electronic refurbishers and one storage facility run by the City of Toronto. These visits provided information of 50% of the Ontario Electronic Stewardship (OES) registered recyclers within the studied area (n = 6) and all of the non – for - profit registered electronic refurbishers within the area (n=2). The three visits to the large-scale electronic facilities and the visit to the City's storage depot were more formal in nature. Despite this, the researcher was still able to spend several hours on location, following the formal tour, conversing with the staff on site. A three-day long visit to one of the non-profit refurbishing facilities yielded a mixture of quantitative and qualitative data from interactions with the volunteers and staff. The largest portion of the ethnographic work was completed while volunteering at one of the primary non-profit refurbishing location in Toronto throughout the summer. During these visits, the researcher was able to assist in a number of refurbishing and recycling tasks. She was also provided with an opportunity to engage in in-depth conversations with all of the volunteers and staff. The researcher transcribed the main ethnographic data, recorded during these visits, immediately after the completion of each visit. The researcher's personal experience while recycling and refurbishing electronics was also recorded. The combined transcripts were coded for themes that were in turn combined with other research findings. The qualitative data was highly useful for linking the different perspectives and observations during fieldwork. It was incorporated into one of the 'Network maps' as well as used solely as ethnographic data for providing insight into the characteristics of the participants within the electronic waste management sector.

3.3.3 Surveys

The importance of multi-sector alliances within waste management has been tied to stronger local resilience and sustainability (Baud et al, 2001; Wilson et al, 2009; Gutberlet, 2012 amongst others). Consequently, the integration of a variety of electronic waste management sectors within a municipal management strategy could also yield better economic, environmental and social sustainability. Yet, in order to create an inclusive and functional system, each actor must be able to contribute an appropriate amount of effort to the common goal of sustainable electronic waste management. Formal and large-scale recycling facilities have a demonstrated ability to meet the necessary processing goals to a certain extent. At the same time, some uncertainty is associated with the processing capacity of smaller scale enterprises and individuals engaging in manual disassembly (see section 2.3). In order to address that uncertainty, the capacity of the small-scale entrepreneurs and the informal sector to process a portion of the electronic waste was in part measured through individual surveys. A survey was designed to explore the ability of the individual staff and volunteers at the recycling/refurbishing centres to process electronic material. The survey questions covered information including the participant's age, time commitment to their current position at the refurbishing facility, skills and experience with electronic recycling/ refurbishing, as well as the approximate amount of items that the individual is able to process on a daily basis. The exact survey questionnaire is attached in Appendix I. The surveys were presented to the volunteers and staff during each visit at the two refurbishing centres in Toronto. Participation in the survey was optional. Eleven out of approximately 15 staff and volunteers present at the first refurbishing facility were able to fill out the survey, thus yielding a 75% response rate. A smaller number of regular volunteers and staff were present daily at the second refurbishing location. As a result, only 10 surveys (an approximate 50% response rate) were completed during the visits to the refurbishing centre. The survey data was entered into an Excel file. The data for individual characteristics (age, skills, background, amount of processed materials/day) was summarized via bar graphs. Averages were calculated for the responses to each quantitative question. The responses to the qualitative questions were incorporated into the ethnographic data discussed above. The combined results were used to draw conclusions about the small-scale enterprise's and individual recyclers' capacity to process electronic material and thus assist in the creation of a sustainable electronic waste management system in Toronto.

3.3.4 Material Composition Audit and "Garbage Gazing"

In order to analyze the current electronic waste management system's ability to sustainably process all the necessary materials, further exploration of the general appearance of the said electronics is required. As mentioned previously, many formal waste collection programs have a relatively narrow list of accepted electronic items. In addition to that, it is highly likely that a large portion of electronic waste is not being collected, and thus accounted for, by the formal sector (refer to Section 2.1). Analyzing the general composition of the electronic waste stream in Toronto can point to the appropriate solutions to these issues. Thus, two methodologies are employed to measure the types and amount (in number of units) of materials present in the electronic waste stream in the City of Toronto.

The first methodology is designed to analyze the captured electronic waste by the City of Toronto waste department. The methodology is loosely based on a combination of techniques utilized by Babbitt and colleagues (2009), Kahhat et al. (2008) as well as the researcher's personal experience in conducting waste audits. As a part of their study, Babbitt et al. (2009) calculate the institutional disposal rates of electronic waste at the Arizona State University in 2008. Throughout the data collection, they characterize the discarded electronics into different categories: computer, laptop, monitor, hard drive, printer etc. Their findings are compared to other universities in the U.S. The combined data depicts the state of the institutional electronic waste disposal in the country. Similarly, the researcher was able to obtain a breakdown of the electronics collected by the City of Toronto trucks. The researcher secured a copy of the disposed electronic weight bill, from the City's current recycler. This information was also complimented by the visual audit of the electronic materials present at the two City collection depots as well as City supervised collection event. It was the researcher's original intention to participate in/ or perform an actual audit of the materials present at the collection site. However, logistical barriers (legal necessity for the researcher to be a part of City of Toronto staff, timing of the audit and communication with the City) prevented the physical audit from occurring. Nonetheless, the researcher was able to gain a good understanding of the types of materials collected by the City through visual and photographic observations on site (see photographs in Chapter 4, 5 and Appendix II). These observations yielded an approximate breakdown of the types of materials that are typically collected by the City of Toronto. The data collected at each individual site was recorded in Excel. Graphical representations of the categories and quantity of electronic equipment located on site were produced. The results contributed valuable insight into the City's existing waste management system. Yet, further investigation of the 'non- City collected' items was also required. As previously discussed, the City's collection program is likely unable to capture all of the electronic waste that is present within its geographic area (see section 2.1). Thus, a different methodology was designed to address this second category of available electronic waste.

A sample collection methodology was established to explore the general appearance of electronic waste items found on the curbside in Toronto neighbourhoods. The data collection methodology was loosely based on the research conducted by Cassandra Kuyvenhoven in Kingston, Ontario. As a part of her data collection process, Kuyvenhoven (2013) observed and recorded the items deposited for waste-collection in residential areas. The methodology is titled “garbage walks” (Kuyvenhoven, 2013). In a similar fashion, the primary researcher designed 'electronic garbage – gazing' walking routine in a residential neighbourhood in Toronto. The neighbourhood in question covered an area of approximately 1 square kilometer. The area was approximately 90% residential and 10% commercial. Each evening, prior to the weekly garbage collection, the researcher explored her neighbourhood's front curbs for the presence of electronic waste. If electronic waste was sighted in a certain location, that location was visited again, early on Wednesday morning, prior to the City's waste collection. Each street was routinely visited Tuesday evening and Wednesday morning for the duration of one month (from August 28th to September 28th). The purpose the methodology was to gain knowledge about quantity and type of electronics that were left for formal waste collection but did not end up reaching their intended destination. This small-scale exploratory exercise was intended to aid the overall understanding of electronic waste management activities in Toronto.

In addition to the thorough inspection of electronics designated for curbside pickup, the researcher also recorded any instance of 'electronic garbage sighting' within the City's research area. In both scenarios, the location and type of electronic waste was recorded. Each piece of electronic waste was photographed in its 'primary habitat'. On a few occasions the waste had to be disturbed and relocated from its 'primary habitat' to allow for a more thorough inspection and a higher-quality photograph. Upon the completion of data collection the data was recorded and plotted in Excel. A series of pie charts were created to describe a) types of materials captured by the City b) the types of materials captured by non-City trucks and c) the general categories of materials found at curbside collection sites. The combination of observation methods clarifies the quantity and type of electronic waste available in a few areas in Toronto. Arguably, that data could be representative of the electronic waste that is currently present in the Census Metropolitan Area.

3.4 Limitations of the data collection methods

The initial purpose of the study is to analyze the electronic waste management system in Toronto with a particular focus on current and future sustainability of the overall system. As such, the researcher relied on a number of different methodologies to supply the variety of quantitative and qualitative data. This data was later analyzed to provide a general idea of the current state of electronic waste management in an urban centre. It is important to note that the data collected as a part of this project was limited by the abilities of the sole researcher to access information and perform data collection methodologies. As mentioned in the previous sections, some of the initial plans for data collection had to be modified throughout the project. A major limitation of this research project was the willingness of some of the 'major' actors in the electronic waste management sector to participate in the study. The researcher attempted to communicate the purpose of her study to the best of her ability, however the lack of any initial inside contacts within the electronic waste management sector in Toronto proved communication quite difficult. As such, the results of this study are limited to the information gained from only a portion of the active participants in the waste electronic management sector in Toronto. The main limitations occurred in the exploration of the private, large- scale recycling companies. Only two out of the potential five OES registered recyclers within the Toronto CMA area granted the researcher a visit to their facilities (thus yielding a 40% participation rate). Yet, the researcher was able to complement the above data collection with phone and in-person interviews with four more large-scale recyclers that were not initially listed on the OES web page. Two out of the four organizations claimed to be registered with OES as well. Two other organizations were functioning outside of the OES. Altogether, the researcher estimates to have covered approximately 50% of the private electronic waste recycling organizations in Toronto. Nonetheless the relatively low scope of the private sector was compensated by a more thorough analysis of the non-profit refurbishing sector and the government regulatory program. The only two existing non-profit refurbishing organizations in the Toronto CMA were analyzed through participant observation and quantitative data collection methodologies. Similarly, in-depth interviews and site visits were conducted with the City of Toronto Waste management and Ontario Electronic Stewardship. The data collection from the two government-related organizations covered all of the characteristics of the government regulated electronic waste management sector. The combination of the various types of information collected as a part of the study provided a useful insight into the shape of the electronic waste management in an urban centre.

3.5 Summary of Methodologies

The methods used in this fieldwork are first and foremost designed to address the research questions. A large part of the methodology is dedicated to the exploration of the social and material flow networks that have formed within the electronic waste management sector in Toronto, ON. A complementary set of methodologies supply more detailed information on the current sustainability of the above-mentioned sector and the feasibility of its future sustainability. While the first type of methodology focuses on visual representation of the overall network, the other methods provide complementing quantitative and qualitative information.

A series of visual representations were created via a 'Network Analysis' methodology. These illustrations were used to provide an insight into the existing electronic waste management system in Toronto, thus addressing the primary research question. The 'Network Analysis' methodology was designed from a combination of a traditional Social Network Analysis and Material Flow Analysis methodologies. The data collected for the 'Network Analysis' provides an overview of the current relationships and flow of materials between different participants in the electronic waste management system in Toronto.

Further data collection methodologies, in the form of a ‘System Audit’, were designed to compliment the 'Network Analysis' and provide an analysis of the sustainability of the electronic waste management sector. The research questions were in part addressed through site-visits to a number of electronic recycling and refurbishing facilities; individuals surveys and interviews; participant observation and 'garbage walks'. Even though the data collection was somewhat limited in its scope (see section 3.3), the combination of the different types of information collected during fieldwork yielded an equally large number of results. Together the data collection and analysis methodologies were used to acquire a deeper insight into the state of sustainability of an electronic waste management system in an urban centre.

CHAPTER 4: Results

The role and characteristics of the provincial electronic waste management system

4.1 Introduction

The Toronto Census Metropolitan Area hosts a multi-layered electronic waste management system. The sheer size of the City, its geographic location, and continuous population growth results in a high flow of electronic waste. The city's geographic area falls under the jurisdiction of two government bodies: the Ministry of the Environment (and thus the Ontario Electronic Stewardship) and the City of Toronto Waste Management department. The number of different layers of management affects the structure of the electronic waste processing networks within the Census Metropolitan Area of Toronto. The City's current e-waste management system can be separated into several different categories of participants.

The formal, provincial electronic waste program is managed by Ontario Electronic Stewardship, under the supervision of the Ministry of the Environment. Ontario Electronic

Stewardship (OES) in turn oversees a portion of the private, large-scale recycling and refurbishing sector. Several non-profit refurbishing organizations also fall under the provincial electronic waste management program.

On the municipal scale, electronic waste is managed by the City of Toronto Waste Management department. The City's program includes the curbside collection of electronics as well as several other collection programs for the residents to discard their electronic waste. The city's collection is in-part affected by the informal electronic waste processing sector.

While individual categories of actors play a role in the overall sustainability of the electronic waste management process, some actors have a stronger capacity to influence others. This chapter will describe the provincial electronic waste management system and the two categories of stakeholders that fall within it (electronic waste processors and non-profit refurbishers). Their effect on the environmental, economic and social pillars of sustainability will be discussed. While some analysis of the peculiarities of electronic waste processing in Toronto will be included in the chapter, a large portion of the analytical discussion will be reserved for Chapter 7.

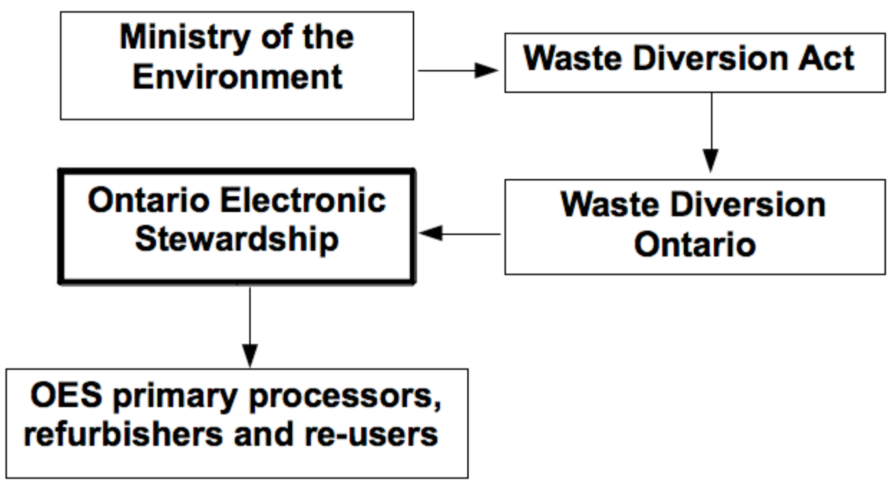
4.2 The overall role of Ontario Electronic Stewardship and the Ministry of the Environment

The provincial regulation of electronic waste in Ontario can be viewed as a two-fold system. On the provincial level, the management of electronic waste is governed by the Ministry of the Environment. Yet, the Ministry does not oversee the program directly. It in turn designates Ontario Electronic Stewardship (OES) to manage the daily aspects of electronic waste processing. The area supervised by OES includes the Greater Toronto Area and City of Toronto (Waste Diversion Act, O. Reg. 394/04, 2002).

The regulatory role executed by Ontario Electronic Stewardship provides the organization with an ability to shape multiple characteristics of local electronic waste processing. OES has an opportunity to directly influence a) the types of organizations that are selected to process electronic waste, b) the categories of waste that are selected for processing and c) the final destiny of the processed electronic waste. The following sections will describe these aspects in detail.

Before diving into our discussion, it is important to point out that many aspects of Ontario Electronic Stewardship are dictated by a regulation that has been written and approved by the Ministry of the Environment. The system by which the OES is regulated is multi-layered. The Waste Diversion Act, created by the Ministry of the Environment in 2002, mandates the existence of Waste Diversion Ontario (WDO) - "a permanent, non-governmental organization" that consists of both industry and other non-government representatives (Ministry of the Environment, 2012). One of the main roles of WDO is to create a source of funding, or fees, to support the existence of provincial regulatory programs for several types of waste (Ministry of the Environment, 2012). Electrical and electronic waste is considered one of the priority waste types that require a special program under the Waste Diversion Act (Ministry of the Environment, 2012). As a result, the Ontario Electronic Stewardship (OES) program was created by the WDO, as per the mandate from the Waste Diversion Act, which was in turn written by the Ministry of the Environment (Interviewee #26, October 11, 2013). The breakdown of the complex regulatory system pertaining to OES is visualized in Figure 4.1. The multi-layer interactions allow for little flexibility within the established OES program. At the end of the day, however, it is OES who interacts with the local electronic processors. Its role as a type of a mediator between the local market and the Ministry of the Environment includes the reception of feedback on the current structure of the regulatory program. The majority of the processors and the public identify OES as the entity that has a direct ability to influence multiple characteristics of the system. While that may not be necessarily true, for the purpose of this discussion we will portray Ontario Electronic Stewardship from the perspective of the interviewees from the local electronic waste management sector.

Figure 4.1 Regulatory process behind Ontario Electronic Stewardship



4.2.1. The provincial program's role in the growth of local electronic processors

One of the prominent roles of Ontario Electronic Stewardship is the formal designation of the local organizations as the registered recyclers and refurbishers in Ontario. Participation within the Ontario Electronic Stewardship program has a number of benefits and disadvantages. The registered organizations benefit from the primary access to the electronic waste that is overseen by OES. At the same time, these companies are required to meet the rigorous processing standards to become registered in the formal program. The model by which the OES program is run often results in a level of market competition that impacts the small-scale electronic waste processors. At the end of the day, a number of processing companies prefer to remain outside of the registered program. The description and analysis of the above characteristics follows.

Ontario Electronic Stewardship currently uses a two-fold system to manage electrical and electronic waste in Ontario (Interviewee #26, October 11, 2013). The first is the "allocation program". Within this program, old electronics are dropped off by individuals at over 500 OES-approved collection sites within the province (OES, 2014f). The electronics are then collected by a contractor and brought to consolidation sites that are supervised by OES. The material is later picked-up from the consolidation site and processed by one of the registered recyclers or refurbishers (Interviewee #7, May 31, 2013; Interviewee #26, October 11, 2013). Upon the completion of the recycling or refurbishing process, the final materials are sent to downstream processors (metal smelters, plastic manufacturers etc.). The allocation program is responsible for approximately 80% of the total material diverted by OES (Interview #10, 2013). That amounts to approximately 60 500 tonnes out of the 75 700 total tonnage processed in 2012 (OES, 2014). The allocation program was the first program to be introduced into the existing electronic waste management market in 2009, upon the creation of OES itself (Interviewee #7, May 31, 2013).

The allocation program does have its benefits (mainly in the form of formal diversion of electronics that would not have been previously collected). Yet, during the fieldwork interviews, many local processors focused on identifying its negative attributes. The program has a potential to strongly impact the structure of the competition within the local electronic waste market. The allocation program limits the access to the collected electronics to the companies registered under OES (Interviewee #7, May 31, 2013; Interviewee # 15, June 28, 2013). As a result, these companies benefit from the system, while non-registered companies struggle to compete for that same material in the market (Interviewee # 15, June 28, 2013).

The second part of the program is the so-called “bounty program”. Under this program, the processors are paid by OES to collect material directly from different companies. It has been suggested, however, that the fee per tonne of collected material that OES is able to pay is somewhat inflated compared to the market prices (Interviewee #7, May 31, 2013). Unlike the private electronic waste processors, OES is subsidized by the industry (i.e. electronic ‘stewards’). Each ‘steward’ is expected to supply the provincial electronic waste management program with a part of the collected fees from the sale of an electronic product (OES, 2014d). These fees are expected to support sustainable end-of-life disposal of the product. In reality, most ‘stewards’ incorporate the ‘eco-fee’ into the price of the product, thus redistributing the cost onto the consumer (Lepawsky, 2012). The details of the ‘eco-fee’ transactions are beyond the scope of this thesis. However, these fees are likely responsible for OES’s ability to pay higher prices per tonne of collected electronic waste. The higher price in turn affects the electronic waste market in several ways. First, more companies are motivated to sell their old electronics to a registered OES collector and/or processor. Second, the relatively high price per/ tonne creates more competition between the OES and non-OES registered companies for the electronic waste. This often results in the smaller-scale non-registered companies struggling to survive in the market (Interviewee #9, June 4, 2013).

Overall, the two OES electronic waste collection and processing programs directly affect the structure of the local electronic waste market. Both the allocation and bounty programs appear to benefit the OES registered companies while creating tougher competition for the smaller-scale non-registered companies. This type of competition seems to be structured to promote more companies becoming registered with OES. However, this type of expansion is not one of the provincial program's priorities.

It is important to point out that OES remains a 'product' stewardship organization first. This stance is different from an organization whose sole focus would be on 'environmental' conservation (Interviewee #7, May 31, 2013). As such, their two mandates include a) ensuring that the Stewards pay necessary fees for the proper management of their electronic materials upon disposal and b) ensuring that a certain quantity of electronics is diverted from landfill (their target for the material tonnage is set annually; e.g. the 2013 target was 82 400 tonnes) (Interviewee #26, October 11, 2013). As a result, OES does not actively encourage all of the recycling and refurbishing companies in the province to register with them. As long as their set target is fulfilled through the participation of the currently registered processors, they do not require contribution from other companies. Nonetheless, they remain open to companies who are interested in joining the program, as long as they are able to meet the Recycler Qualification Office standard (RQO, 2014)[6]. At this time,

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6 Recycler Qualification Office is a bureau responsible for establishing and regulating the standards for the collection and processing of end-of-life electronics in Ontario. The RQO is the auditor that approves the entry of each individual recycler, refurbisher and collector of electronic waste into the OES program. The office operates under the "Electronic

however, there are many companies who are unable to meet the requirement of RQP, and therefore, are not able to participate in the OES allocation and/or bounty program (Interviewee #26, October 11, 2013).

The standardized processing requirement is one of the few reasons for a number of local recyclers and refurbishers' nonparticipation within the OES program. While OES does include over 20 refurbishing and recycling companies throughout Ontario, many companies continue to operate outside of the formal program. For some, even the relatively rigorous standards to which OES adheres are not satisfactory enough. Some members of the Toronto recycling and refurbishing community prefer to adhere to their own environmental standards. For example, one Toronto recycler opts to schedule electronic waste pick-ups only twice a month in order to limit the environmental impact of truck collection (Interviewee # 17, August 8, 2013). Several Toronto companies also claim that they do not require the further benefits from OES as they already operate at full capacity (Interviewee # 17, August 8, 2013; Interviewee #18, August 8, 2013).

Evidently, Ontario Electronic Stewardship has a capacity to strongly affect the structure of the local electronic waste management market. Its ability to regulate the distribution of the electronic material directly impacts the growth of the local electronic waste processors. In general, it appears that the companies registered within OES are benefiting from the existing provincially regulated system. On the other hand, the 'outsiders' are forced to survive in much tougher levels of local competition for material. While a few organizations

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Products Recycling Association (EPRA), a national, non-profit entity, created by Canada's electronics industry" (RQO, 2014).

are uninterested in joining the provincial program, their long-term economic sustainability remains in question.

4.2.2. Electronic waste processors inside and outside of the OES program

The e-waste processors in Toronto have an ability to influence the local electronic waste management system. These recyclers and refurbishers process by far the largest quantity of local electronic waste. As a result, they directly impact the distribution of e-waste from its source to its final destination. The success of these companies in turn depends of their ability to secure the necessary amount of e-waste. As mentioned in the previous section, OES has an ability to impact this factor. Thus, company's participation in the formal provincial e-waste program can determine its long-term sustainability.

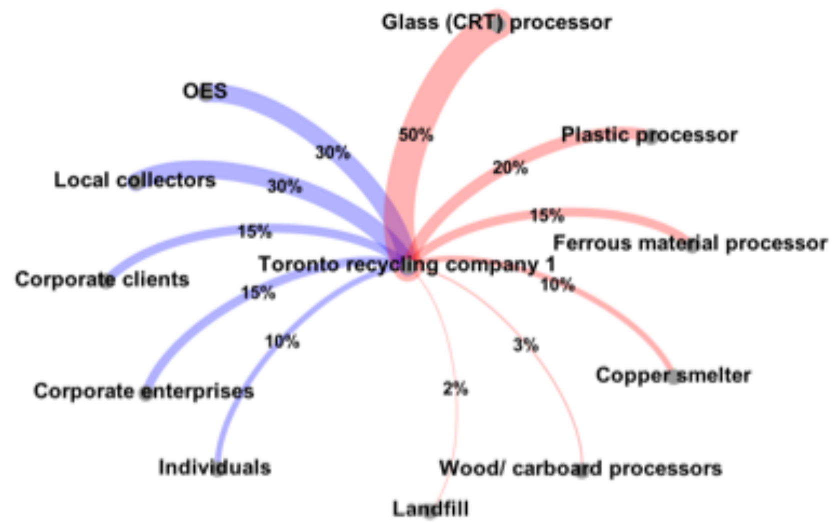
The local processors of electronic waste in part influence the flow of relevant material in Toronto. Each processor is usually responsible for creating their own connections with clients (source of electronics) and downstream recyclers (metal smelters, plastic manufacturers etc.). Individual company's network of connections is visualized in Figure 4.2. All five organizations interviewed during my fieldwork have a very different breakdown of the sources and final destinations for their material.

Firstly, as it is evident in the material flow charts (Figure 4.2), the amount of material that is being processed varies significantly with each company. While some companies process over 6000 tonnes per year, others average at less than 10 tonnes. Such a discrepancy in numbers can be tied to the source of the electronic waste, which greatly differs between the companies. For some organizations, the main source of material comes from small commercial enterprises and local residents (Figures 4.2 d and e). At the same time, some of their competitors service major financial institutions or even whole counties in Ontario (Figures 4.2 a, b, and c). The quantity of e-waste produced by the residential and small corporate sector is small in comparison to the government, financial and large private organizations. As a result two types of main companies emerge from the local market: the larger-scale mechanical recyclers (Figures 4.2 a and b) and the smaller-scale recyclers and refurbisher (Figures 4.2 c, d and e). While the source of e-waste plays a role in total quantity of materials secured by a company, participation in the formal OES program can also act as a contributing factor.

The strength of Ontario Electronic Stewardship's role in the successful economic development of e-waste processors is evident in the results of the fieldwork investigation. From the sample of five electronic waste processors in Toronto, interviewed during fieldwork, three were registered with OES while two were not. As it is apparent in Figure 4.2, the two non-registered organizations processed a significantly smaller quantity of electronic waste (in metric tonnes per year) than the other three. While Toronto Recycling companies 1, 2 and 5 (OES registered companies visualized in Figures 4.2 a, b and c) processed 1400 tonnes/ year, 6000 tonnes/ year and 800 tonnes/ year respectively, Toronto Recycling companies 3, 4 (non-OES registered and visualized in Figures 4.2 d and e) only processed 150 tonnes/ year, and 10 tonnes/year in 2012. This distribution of material is likely influenced by the nature of the 'allocation' and 'bounty' programs described in Section 4.2.1. Ontario Electronic Stewardship's ability to reimburse their collectors and processors for a tonne of collected/ processed material creates stronger competition within the market. Clients (sources of e-waste) are largely interested in making profit from the disposal of their e-waste. As a result, it becomes difficult for a non-registered collector or processor to remain competitive with OES registered companies (Interviewee #19, August 12, 2013). This characteristic of material flow points to the potentially alarming consequences of remaining outside of the OES program.

Figure 4.2. Material flow diagrams describing the inputs (**blue**) and outputs for downstream recycling or disposal (**red**) and refurbishing or re-use (**green**) of electronic waste (in percentage of total tonnes of processed material) for five Toronto electronic recycling companies for the 2012 year

a) OES registered processor; Toronto recycling company 1 1400 tonnes/ year



b) OES registered processor; Toronto recycling company 2 6000 tonnes/ year

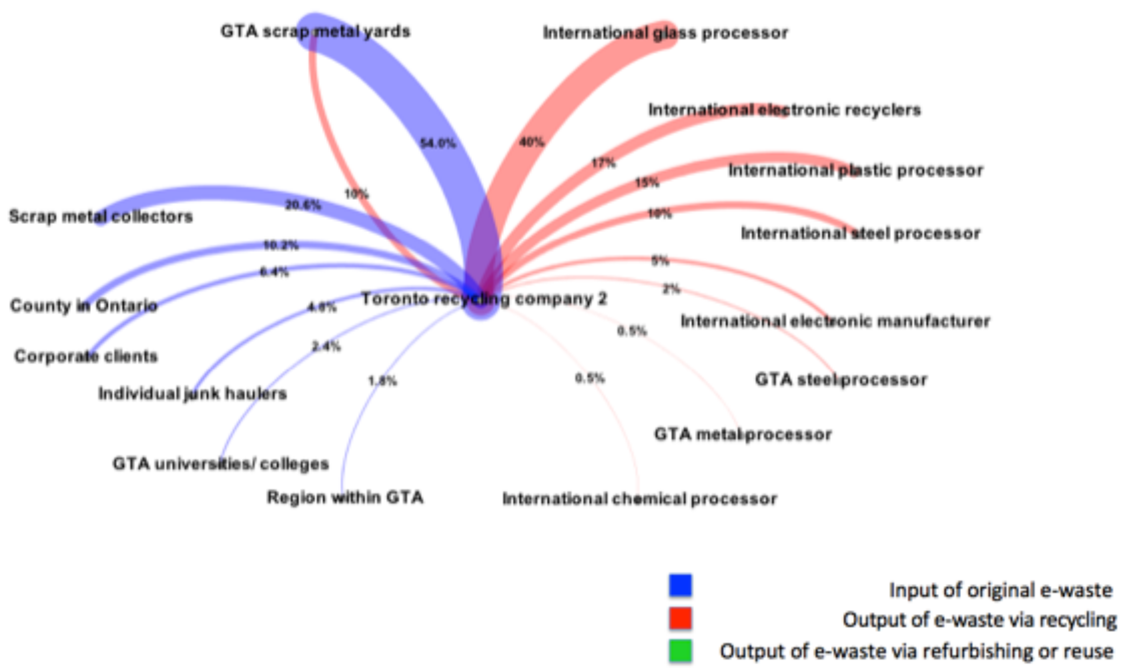
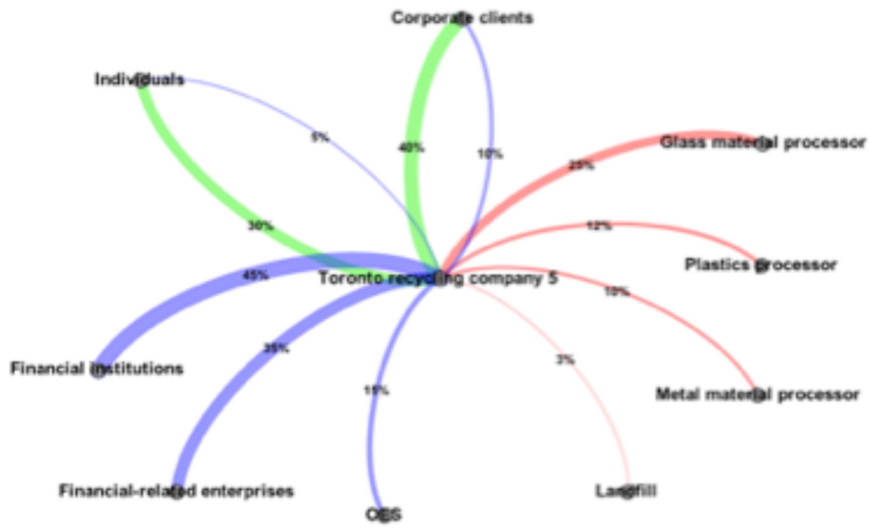
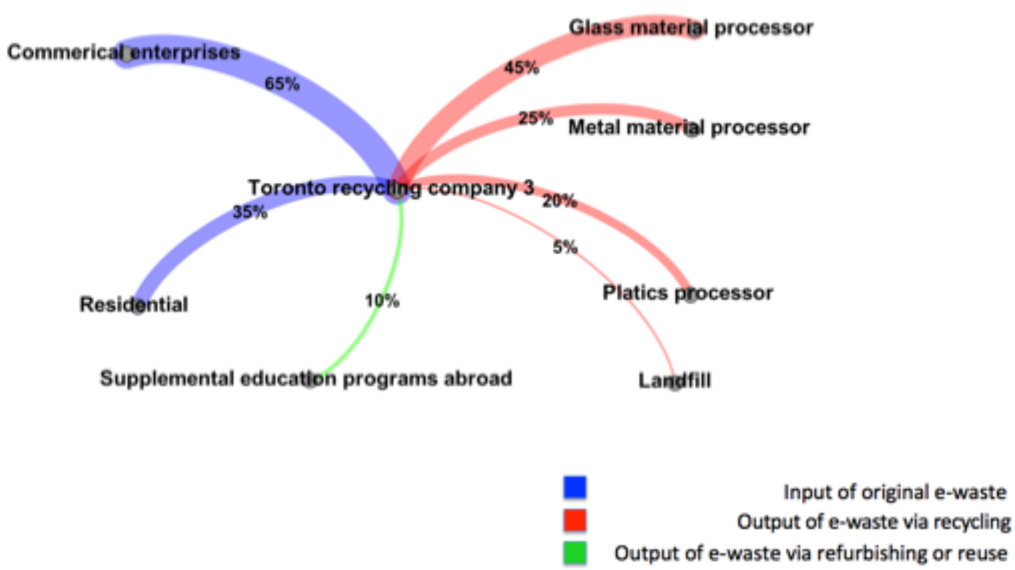


Figure 4.2. continued from previous page

c) OES registered processor; Toronto recycling company 5 800 tonnes/ year



d) Non-OES registered processor; Toronto recycling company 3 150 tonnes/ year



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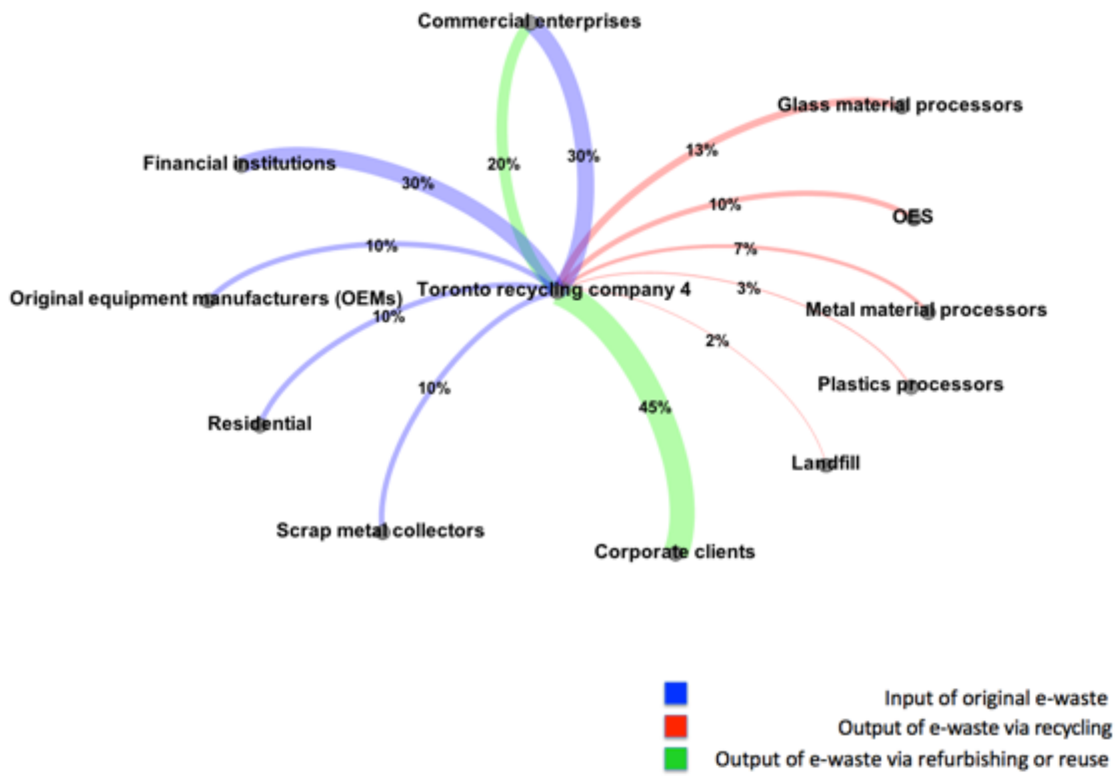
e) Non-OES registered processor; Toronto recycling company 4

under 10 tonnes/ year



As with any local business, the quantity of processed material likely plays an important role in the long-term sustainability of an electronic processor. Based on the above fieldwork results (Figure 4.2) it appears that OES is limiting the economic development of the smaller-scale electronic waste processors. Such development could have several negative effects on the sustainability of the electronic waste management system. Baud et al (2001), among others, have pointed out the importance of alliances between the different sectors of waste management (formal, large-scale; small-scale; manual recycling and informal). The development of each of the sectors can positively influence the environmental, economic and social aspects of urban sustainability. As demonstrated in our literature review, each type of electronic processors displays a number of positive and negative characteristics. The large-scale processor's efforts often result in a higher rate of production of recyclables (Section 2.3 and 2.4). Yet, their preference for mechanized shredding of electronics can affect the quantity and quality of recycled precious materials (Hageluken, 2006). The mechanized recycling process also necessitated the preference for recyclable materials with only the highest content of precious minerals. As a result, items with lower valuable weight content and high plastic composition (toys, miscellaneous household items etc.) are not accepted for large-scale disposal (Darby and Obara, 2005). Most importantly, the large-scale mechanized recycling facilities rarely provide opportunities for electronic waste reuse and refurbishing. According to Williams et al. (2008) and Kahhat et al. (2008) re-use of electronics can play an important role in the local economy (please refer to Chapter 2 for more discussion). My analysis of the large- scale electronic processors in Toronto did not indicate a commitment to local refurbishing or reuse (see Toronto recycling company 1, and 2 in Figures 4.2 a and b). At the same time, the smaller-scale enterprises (Figures 4.2 c, d, and e) were able to refurbish or reuse a portion of their e-waste. [7] Consequently, both the large-scale and smaller-scale sectors occupy an important role in the electronic waste management system. Prioritization between one or the other could eliminate some of the useful attributes, such as local refurbishing and re-use of electronics. Interestingly enough, the official OES policy does emphasize the importance of refurbishing as well as recycling. The actual execution of refurbishing program will be discussed in the following section.

[7] The smaller-scale enterprises' ability to refurbish and reuse electronics is in part influenced by the quantity of electronics that they process on daily basis and the number and type of staff members that they employ. These characteristics will be discussed in more detail in Chapter 6.

4.2.3. The provincial program's allocation of material for recycling and refurbishing

As the provincial overseer of electronic waste management, Ontario Electronic Stewardship influences the fate of the different categories of electronic waste. Its list of 'acceptable materials' dictates the types of electronics that are collected in the local municipalities, including the City of Toronto. Similarly, its allocation of resources between recycling and refurbishing impacts the focus of the electronic waste market. The direct effects of the above characteristics of OES on the local sustainability of e-waste management will now be discussed.

Currently, forty-four electronic items are being accepted for collection by OES and its registered processors. Out of the 44 items, 20 fall under the IT category of devices while the majority of the rest are represented by telephones and audio/video devices (OES, 2014e). This distribution is similar to the pattern of prioritization of electronic recyclables described by Darby and Obara (2005) (Section 2.4). In many urban areas, it is highly unlikely that the majority of electronic devices that require disposal fall primarily within the above three categories. The concentration of collection efforts on solely the IT and computer related devices is likely omitting a large potion of other miscellaneous electronic devices (Darby and Obara, 2005). An evaluation of the curbside electronic waste found in a central Toronto neighbourhood during fieldwork, supports the above hypothesis.

The City of Toronto currently provides its residents with curbside collection of electronic devices, as a part of its regular waste collection services.[8] This collection pattern provided the researcher with an opportunity to investigate multiple characteristics of the

[8] A more in-depth description of the collection processes will be provided in Chapter 5

actual discarded electronics in the City. Figure 4.3 visualizes the breakdown of the electronics that have been deposited by the residents of a central Toronto neighbourhood for the City collection. The types of electronics were compiled according to categories found in the Waste Diversion Act and related OES documentation (Waste Diversion Act, O. Reg. 394/04, 2002; OES, 2014b). The categories were then separated into the types of material that are currently accepted by OES (and thus by the City of Toronto) and those that are not yet included in the list. As it is apparent in Figure 4.3, over 50% of the items (in number of units from the total) that were found on the curb are not currently accepted for recycling and refurbishing in Ontario[9]. The categories of items that fell outside of the OES accepted list were: kitchen appliances (21%), household appliances (11%) and miscellaneous small electronics (such as toys, personal appliances etc) (21%) (Image 4.1).

Image 4.1 Examples of electronic waste items that are not accepted for processing by OES

[9] The reader must also note that the geographic scope of the sample and the duration of the study was not meant to provide broad-scale statistical evidence. It is nonetheless useful to depict the general state of curbside electronic recycling in the City.

Figure 4.3 The breakdown of electronics found on curbside in a central Toronto neighbourhood, prior to the City of Toronto's weekly collection. The percentages are based on a number of units in each category divided by the total number of units recorded during the month-long data collection. The items are broken down in OES acceptable categories (blue) and non-OES acceptable categories (red).

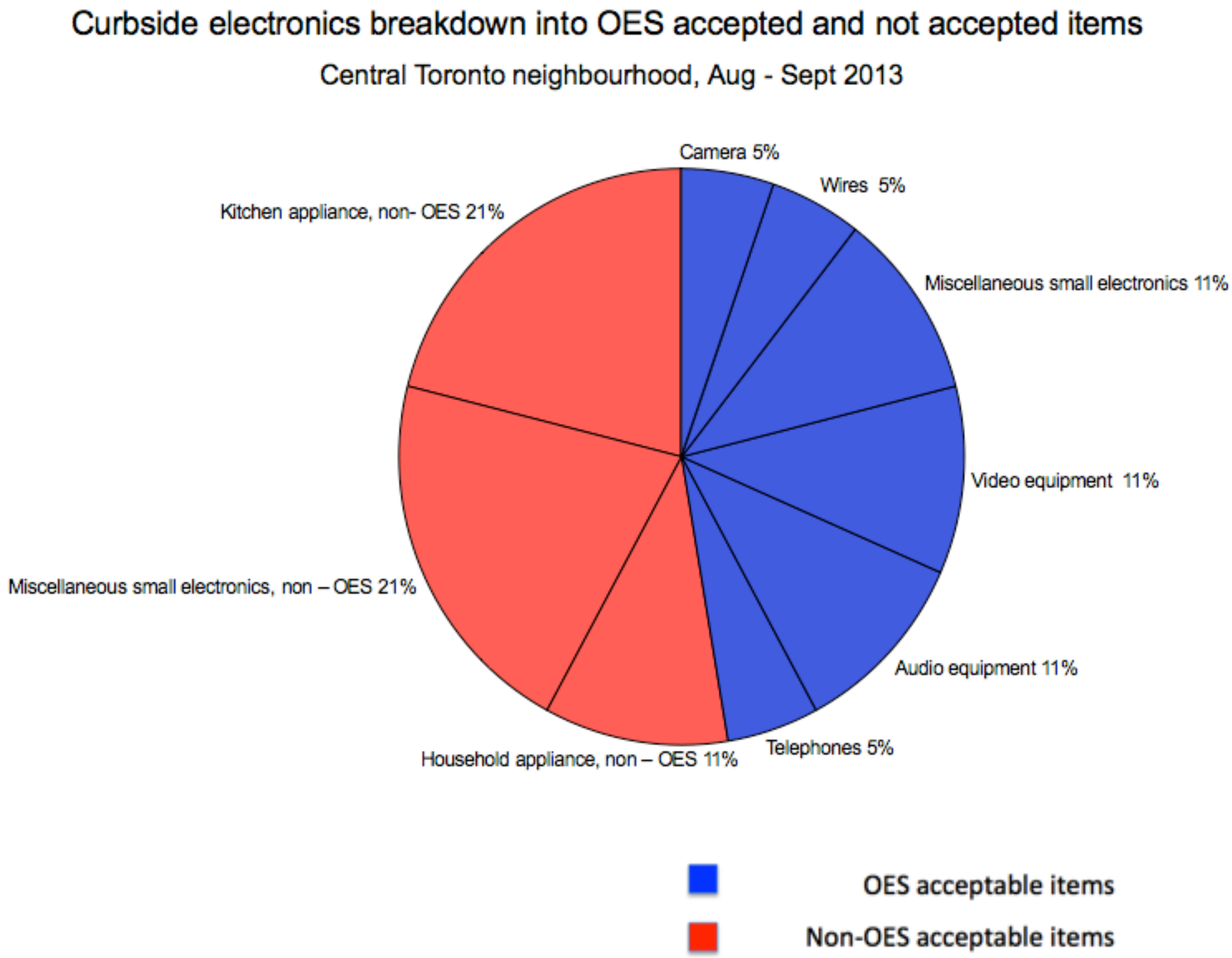
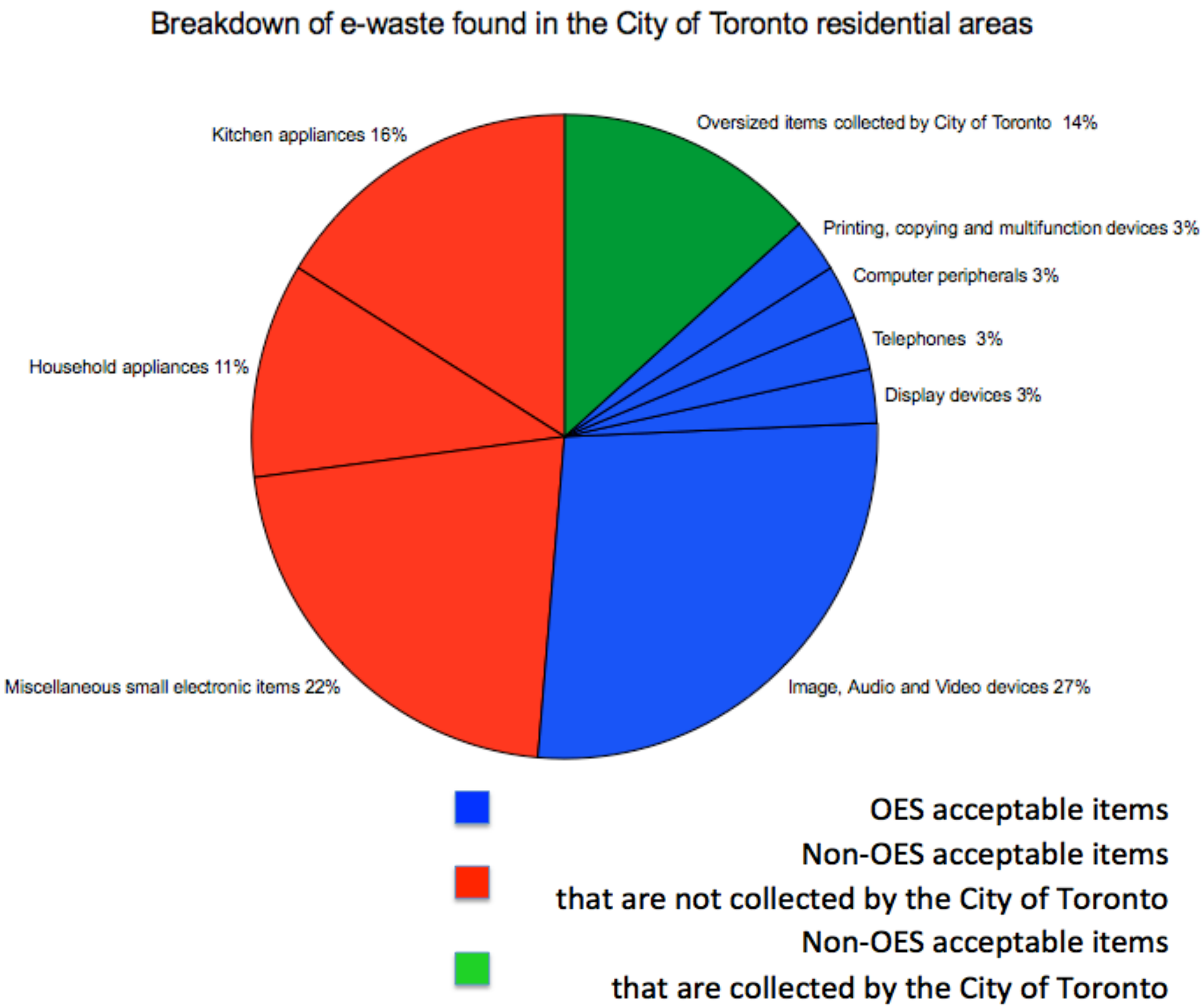


Figure 4.4 The breakdown of electronics found at random in various Toronto neighbourhoods. The percentages are based on the number of units for each category divided by the total number of units recorded during the whole fieldwork season. The items are broken down in OES acceptable category (blue); non-OES acceptable category that is collected by the City of Toronto (green) and non-OES acceptable category that is not still collected by the City of Toronto (red).



The fieldwork investigation also provided an opportunity to explore the content of electronics found at random throughout the City. The sampling methodology for Figure 4.4. was not specific to one neighbourhood (Chapter 3) and thus provides a broad portrayal of the types of e-waste items found in Toronto in general. The findings are in agreement with the categorization of the curbside e-waste described in Figure 4.3. Approximately 50% of the electrical and electronic devices found on curbside at different parts of the City did not fall within the list of items accepted for formal recycling. Those items yet again included: kitchen appliances (16%), household appliances (11%) and miscellaneous small electronic items (22%). The items found on the curb also included oversized electronic items (14%) such as ovens, furnaces and fridges (please refer to Image 4.3). These items are collected as a part of the bulky items program (City of Toronto, 2014b). Based on the above sample investigation, between the two curbside samples, approximately half of electronics discarded by the residents are not being currently collected for recycling.

Unfortunately, the current bureaucratic structure of OES leaves very little opportunity to address the above issue. The electronic items that are accepted by OES have been selected by the Minister of the Environment himself. If a board member or a steward within OES were to suggest an addition of a new item to the existing list, that item has to be first approved by the Minister. As a result, the existing process allows for very slow adaptation to the current market (Interviewee #26, October 11, 2013). At the same time, this inability to 'change' is clearly affecting electronic waste collection and processing on both the provincial and municipal level. By omitting a relatively large portion of electrical and electronic devices, the 'formal' program is actively sending these devices to the landfill. This pattern of disposal hardly meets the provincial and municipal mandate for ‘sustainable’ waste management.

The second major limitation of the current formal electronic waste management collection is the apparent prioritization of electronic recycling over refurbishing. Ontario Electronic Stewardship does theoretically mandate refurbishing as well as recycling of electronics. There are currently 14 companies (4 within Toronto CMA) that are registered as refurbishers with OES (OES, 2014). These organizations are expected to report on the quantity of material that they process annually. Yet, the reporting program is not strictly enforced. Only a few of the organizations supply information on their annual material flow. As a result, OES has very little information on the actual quantity of electronic waste being refurbished in Ontario. In fact, their annual targets for electronic waste diversion are set primarily in terms of recycled material.[10] While promoting the idea of electronic refurbishing and re-use, OES seems to prefer to leave that sector of electronic processing to its own devices. Large quantities of electronics are already a part of an existing take-back-program by their own manufacturers. Another large portion of refurbishing occurs within the informal electronic management system, the details of which are beyond the grasp of OES (Interviewee #26, October 11, 2013) (Section 5.3). All in all, formal electronic refurbishing occurs on a much smaller scale than recycling in Ontario and Toronto CMA. At the same time, the focus of the electronic waste processing community on electronic recycling vs. refurbishing cannot be solely attributed to OES.

Electronic waste refurbishing is commonly not economically efficient enough to sustain an electronic processing organization. As it is visualized in Figure 4.2, most Toronto based

[10] To be addressed in more detail in Chapter 5

companies concentrate their efforts on recycling (red). Very few re-use and refurbishing transactions (green) were reported by the interviewed organizations (Figure 4.2). There are many reasons behind such allocation that are beyond the scope of this thesis (obsolescence being one of them). However, the main justification is relatively unambiguous. Many of the discarded electronic devices are either not reparable or, in most cases, not desirable enough for further re-use by consumers (Interviewee #7, May 31, 2013; Interviewee # 16, July 9, 2013; Interviewee #26, October 11, 2013). Additionally, it could be speculated that a large majority of electronics that are better suited for profitable refurbishing (newer computer models etc.) are not yet present in the waste collection stream (often as a result of hoarding; Chapter 2). Very few consumers are looking to purchase an older, second-hand electronic device. As a result, many charities have stopped accepting the majority of old electronics (Interviewee #7, May 31, 2013). This pattern was observed by one of the recycling companies, who were commonly present at Toronto residential electronic waste collection events with a number of other organizations and charities.

> "At [the events] ... one person would come up to [us] and ask "Well can't you reuse this? It's still good." and we would say "Well, this is not what we do, we are recyclers but you can take it to [the charity] place instead"...They take it to [the charity booth], but [the charity would] say that if its not a newer computer, they are not interested either..." - Interviewee #7, May 31, 2013

These circumstances act a major barrier for any organization's involvement in electronic waste refurbishing/ re-use. Additionally, this type of consumer behaviour may continue to drive the continuous production of newer and 'better' devices, thus further driving 'obsolescence' of electronics. This positive feedback loop of behaviour will not only affect the 're-usability' of electronic items but the local community's ability to reduce waste production all together (an issue that will be further discussed in Conclusions). If the market for second-hand electronic devices continues to diminish, economic sustainability of electronic refurbishing could be at risk. Currently, a few niche organizations (registered with OES) do maintain a strong commitment to electronic waste refurbishing. Yet, many of these organizations are non-profits and thus receive supplementary funding to support their refurbishing efforts.

4.2.4 Non-profit electronic refurbishing sector

Currently, there are five non-profit electronic waste reusers/ refurbishers registered with OES. These organizations fill the relatively smaller niche of computer refurbishing sector. As of 2012, there were three non-profit electronic waste processing enterprises located within the fieldwork area, in Toronto. Unfortunately, by the time fieldwork began in May of 2013, one of the companies closed due to a lack of sustainable profit. The researcher was nonetheless able to establish a relationship with the two remaining companies. The following section will concentrate on describing the unique characteristics of the non-profit electronic waste management work that were unveiled during the fieldwork.

Non-profit electronic refurbishing and reuse sector plays a number of very specific roles within the electronic waste management market. First and foremost, by eliminating the necessity for recycling, the refurbishers are able to supply second-hand electronics directly into the parts of the market that need them. Secondly, by concentrating their efforts on technical, manual refurbishing, they are able to provide a greater number of technically skilled jobs. Yet, the refurbishing sector is not without its limitations. The sector relies on a consistent in-flow and out-flow of particular types of material. The ever-changing market for electronic devices is foreshadowing an increasingly difficult future for the non-profit electronic refurbishers.

The two Toronto based electronic refurbishers supply materials to the areas of the market that would otherwise struggle to obtain electronics. The first non-for-profit organization (NFP), Renewed Computer Technology (RCT), focuses on equipping schools, charities and other NFPs with refurbished electronics. The organization was established in 1997 to provide better access to information technology (Interviewee #2, May 27, 2013). As such, the majority of electronics they process and supply fall within the Information Technology category. Similarly, the second organization, Free Geek, also specializes in the reuse and refurbishing of mainly computers and computer peripherals. This particular refurbishing centre also supports the use of open source software in order to minimize the costs of electronics to their consumers in the community. The centre primarily acts as a destination for electronic drop-off for residents. The electronics that are refurbished at the centre are sold to the community at low prices. The organization also provides free of charge classes on computer hardware repair and installation, as well as software installation and literacy. These types of activities are very popular with lower income residents of Toronto (Interviewees #14, June 25, 2013). In combination, the two centres provide necessary services to the parts of the Toronto community that would normally struggle to gain access to affordable technology and IT services. These services are beneficial to the promotion of the social sustainability pillar in the urban community.

The refurbishing centres also have the capacity to provide technical training opportunities for the local residents. Both of the non-profit centres include a large group of volunteers that are able to gain technical skills and knowledge. The promotion of the technical knowledge and free information is equally prioritized by both facilities. At the same time, the contrasting organizational structures of the two centres have different effects on the continuity and strength of their training programs.

Renewed Computer Technology has a well-structured intake and training program for its volunteers. In the past, this program has enabled them to employ some of their long-term volunteers, upon the completion of their training. The centre has a large number of regular volunteers (10 to 20 individuals) who are supervised by the full-time staff. The majority of the organization's technicians are full time volunteers, gaining experience for future employment opportunities. The technicians are responsible for the initial testing and subsequent building or recycling of the computer. The initial testing procedure includes several hardware stations. At each station the technicians are required to test the functionality of the electronic devices with the assistance of custom designed software programs (see Appendix for images) (Interviewee #3, May 28, 2013). If the item passes all tests, it gets stored in the inventory. The older and non-functional items get stripped of useful parts (Interviewee #3, May 28, 2013). The electronic parts are either stored for future use or are picked up by OES for recycling (see Appendix for images). Once a client puts in an order, the specific type of material is withdrawn from inventory. It then undergoes a preparation process where the appropriate software is uploaded onto it. In the production area the electronics undergo thorough software 'cleaning' after which the basic Microsoft package is installed onto each computer.[11] Each computer is also equipped with a series of PDF documents that provide basic tutorial on how to use the computer (Interviewee #3, May 28, 2013). The majority of the volunteers have an opportunity to participate in several aspects of the refurbishing process. This provides them with a well-rounded training experience.

Free Geek's organizational structure differs from their counterpart's. The refurbishing centre welcomes any volunteers that wish to gain knowledge about IT and computer repairs. In fact, up until recently, the centre was mainly run by volunteers with only a handful of full time staff (Interviewee #16, July 9, 2013). Decisions were made through unanimous votes of all members and the board of directors (Interviewee # 16, July 9, 2013). Yet, this system has demonstrated a series of challenges. The large number of involved members restricted the possibility of actual unanimity of the votes. Very few decisions for upgrades and structuring of the location were made over the past few years. Additionally, in comparison to the other refurbishing centre, Free Geek has experienced difficulties with volunteer retention. Unlike RCT, their volunteers are not assigned to a supervisor and not expected to contribute to a particular activity on regular basis. Many of the daily tasks are run by new volunteers who receive minimal direction from the one or two paid staff. The lack of organization has its toll on many activities including computer testing and refurbishing. Most importantly, the lack of structure affects the production of the refurbished electronics and thus endangers the long-term sustainability of the centre.

The provision of technical training opportunities and volunteering experience has both

[11] The organization is a registered Microsoft refurbisher. The majority of their clients require Microsoft for their curriculum.

positive and negative effects on the non-for-profit electronic refurbishing sector. The actual provision of skills and training has obvious social benefits to the volunteers themselves and the local economy. These will be discussed in more detail in Chapter 6. At the same time, the presence of volunteers on site does have an economic benefit for the centres themselves. Primarily, the volunteers contribute valuable work effort for free. If organized properly, the centres could maintain operation with a small portion of paid staff and a large body of volunteers. Even so, some of the full-time staff are currently paid through government social assistance and youth training programs (Interviewee #3, May 28, 2013; Interviewee # 16, July 9, 2013). As a result, the organizations are able to reduce their operational costs all together and thus concentrate their efforts on refurbishing. Yet, this type of well-balanced operation relies on the company's organizational structure. As demonstrated in the above comparison, RCT's structure seems to be more befitting to the success of an organization in the non-profit sector. The more rigid management of RCT has proved to be necessary for the long-term maintenance of the training and volunteer program. On the other hand, the relatively relaxed atmosphere in Free Geek has undermined the centre's ability to deliver services to its consumers. The lack of organization has proven particularly detrimental to one of the key aspects of long-term economic sustainability of the centre – outflow of processed electronics.

The long-term economic sustainability of the refurbishing centres in part depends on the supply of the necessary materials and the centre's consequent ability to process them. The material flow breakdown of the two refurbishing organizations provides a more detailed insight into the source and final fate of the electronic waste (Figure 4.5). These material flow diagrams provide a significantly different picture from the material flow breakdown for electronic recyclers in Figure 4.2. The main dissimilarities include the primary source of the materials and their final destination.

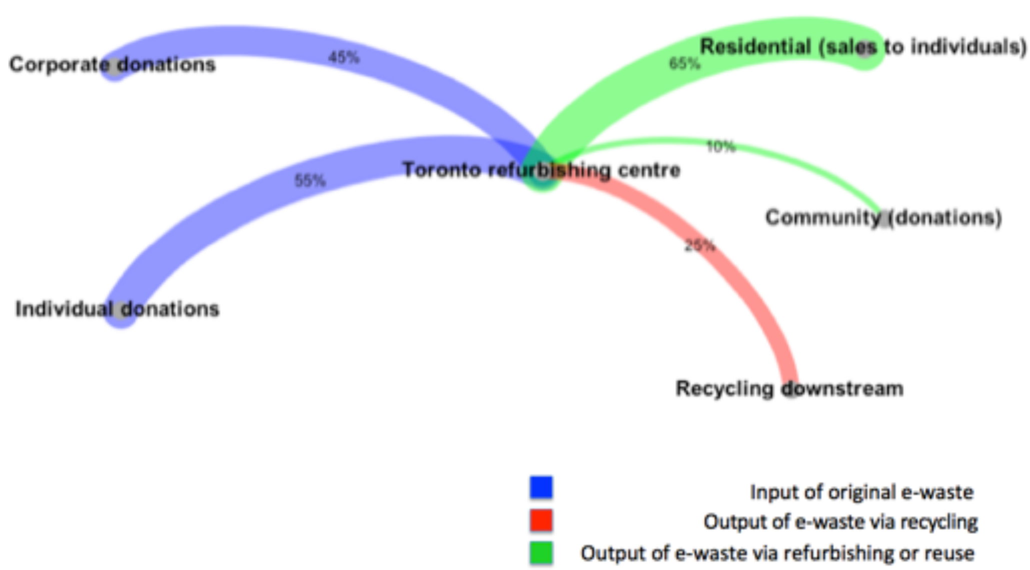
Figure 4.5. Material flow diagrams of the inputs (blue) and outputs of electronic waste for refurbishing (green) and recycling (red) for a Toronto refurbishing companies in 2012

a) OES registered refurbisher; Toronto refurbishing company 1, RCT

13 000 units/ year or approximately 200 tonnes

b) OES registered refurbisher; Toronto refurbishing company 2, Free Geek

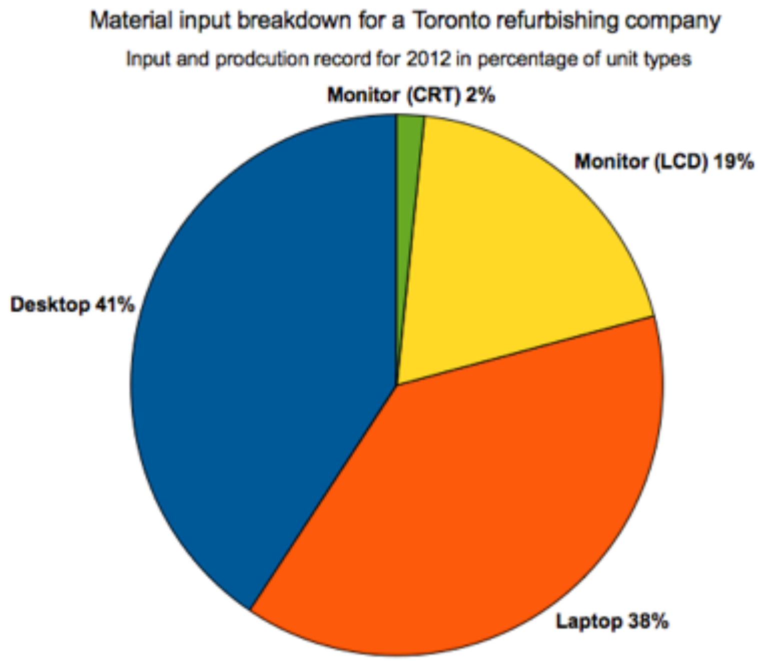
200 units/ year or approximately 2 tonnes



As mentioned previously, one of the main limitations of the economic efficiency of electronic refurbishing is the supply of quality material that is still sought after in the electronic market. One such material category is computers and computer peripherals. As a result, both of the Toronto refurbishing companies concentrate their efforts on IT refurbishing. For example, as visualized in Figure 4.6, computers and computer peripherals compose nearly all of the material inputs and outputs for Free Geek for 2012. Similarly, RCT's input and output of material for 2012 (as recorded in their annual log) also consist of mainly IT equipment (Figure 4.8). Consequently, both organizations need to maintain strong relationships with the parts of the market that are able to supply consistent quantities of the said material. They are in constant competition with the for-profit electronic recycling, as they solely depend on the free donations of the electronics (Interviewee #2, May 27, 2013). The main sources for RCT's materials include federal and provincial government, financial institutions and corporate clients (Figure 4.5). It is these types of organizations that are often able to supply large quantities of relatively new electronics as a result of the regular upgrades to their system (Interviewee #7, May 31, 2013). So far, RCT has been able to maintain a strong flow of materials to their centre. In 2012, they reported processing about 200 tonnes of electronics (Figure 4.5), a notably larger quantity of electronics than the two non-OES registered recyclers described in Figure 4.2.

Figure 4.6. Breakdown of inputs and outputs for Toronto refurbishing company, Free Geek, for the 2012 year. The percentages are based on the number of units for each category divided by the total number of units recorded in the 'production' log in 2012. [12]

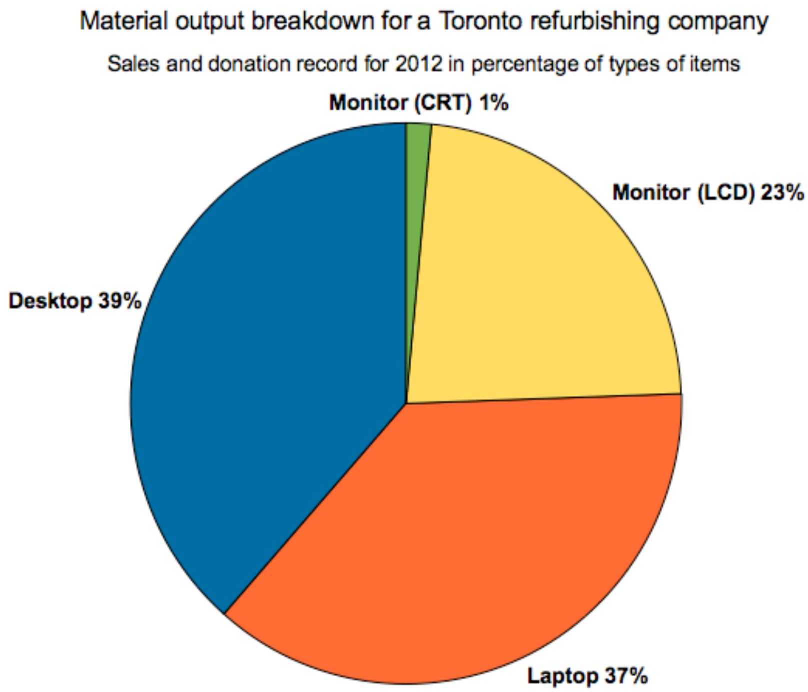
a)



[12] The types of electronics that were recorded in the 'production log' document were mainly restricted to an array of computers and monitors Yet, the researcher was able to spot a small percentage of other household and entertainment electronic devices on the premises. The process of refurbishment and sale associated with those items did not seem to be recorded in the available documentation.

Figure 4.6 continued from previous page

b)

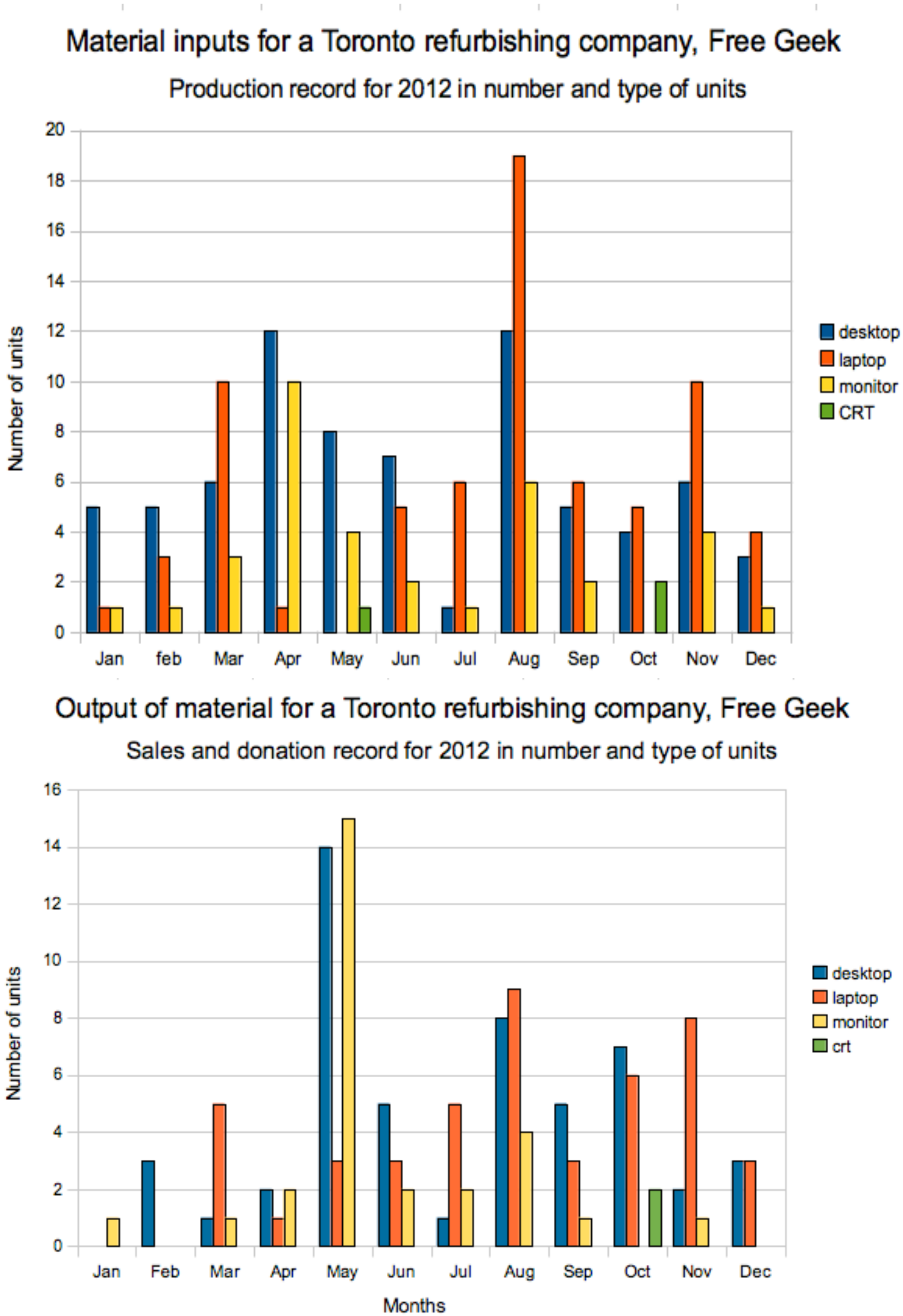


Free Geek currently receives the largest portion of its donations from city residents (Figure 4.5). Yet, this source has not proven to be sustainable. In fact, the Toronto based centre has been struggling to maintain production inputs and outputs for a number of years. Several aspects of the daily functionality of the centre are affected by the lack of organization over the last few years (Interviewee # 14, July 9, 2013). First, the inflow of electronics appears to be relatively inconsistent. The organization's relatively local focus results in a smaller scale of operation compared to other recycling and refurbishing companies that have been discussed up until now. In 2012 the centre recorded processing and selling less than 200 units of refurbishing electronics.[13] The main source of material

[13] The centre does not measure its inputs and outputs by weight. All the transactions in the 'production log' were recorded in a number of units. A very approximate estimate for the weight of 200 computers (based on the weights provided by an RCT report) would be 2.3 metric tonnes.

has been from small, individual donations from residents and local corporations (Figure 4.5). As a result, the fluctuation within the already small inflow of material may have a stronger impact on the centre. The breakdown of the input of electronics during 2012 (acquired from the centre's ongoing 'production log') demonstrates the relative variability with each month (Figures 4.7). The absence of consistent growth of input throughout the year is evident. Clearly, this lack of steady inflow of materials can have a detrimental impact on the centre's long-term economic sustainability.

Figure 4.7. Input and output of materials (in number of units) over a twelve-month period in 2012 for a Toronto refurbishing company, Free Geek



In addition to the struggle related to the input of materials, the non-for-profit sector has to demonstrate an ability to consistently process the supplied electronics. While RCT so far appears successful in the production of second-hand material (delivering over 200 tonnes of electronics to schools and charities in 2012), Free Geek has experienced more difficulties. It is likely that the material output is influenced by the regular time commitment of the staff and volunteers, as well as their total experience refurbishing electronics at the location. At the time of the fieldwork visits, only the paid staff and one or two volunteers were responsible for computer refurbishing. As a result, the output of refurbished materials was relatively low in comparison to the inputs. Figures 4.8 highlights the fact that the majority of the volunteers and staff are unable to commit to more than 20 hours a week at the refurbishing centres. Additionally, many of them are relatively new to the facilities, as they have not spent more than one month volunteering (Figure 4.9). Consequently, the combination of such circumstances could have had an effect on the yearly output of refurbished materials, visualized in Figure 4.10.

Figure 4.8 Average time commitment in hours/ week for volunteers and staff at the Toronto refurbishing centres

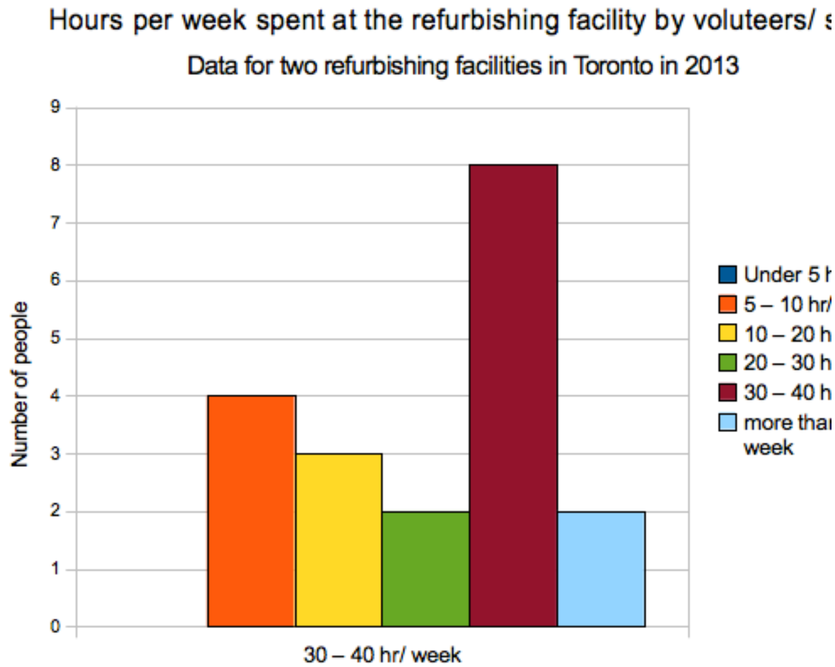
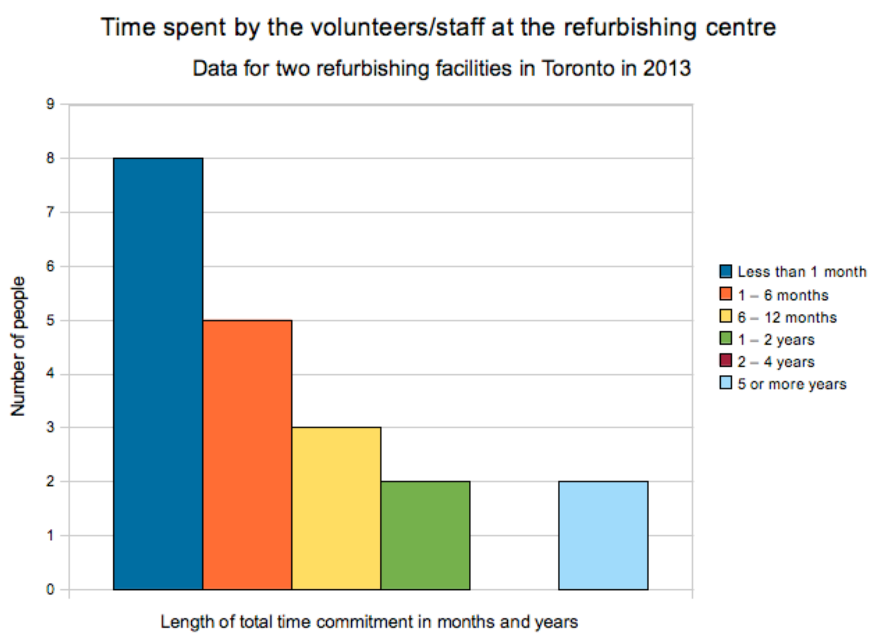
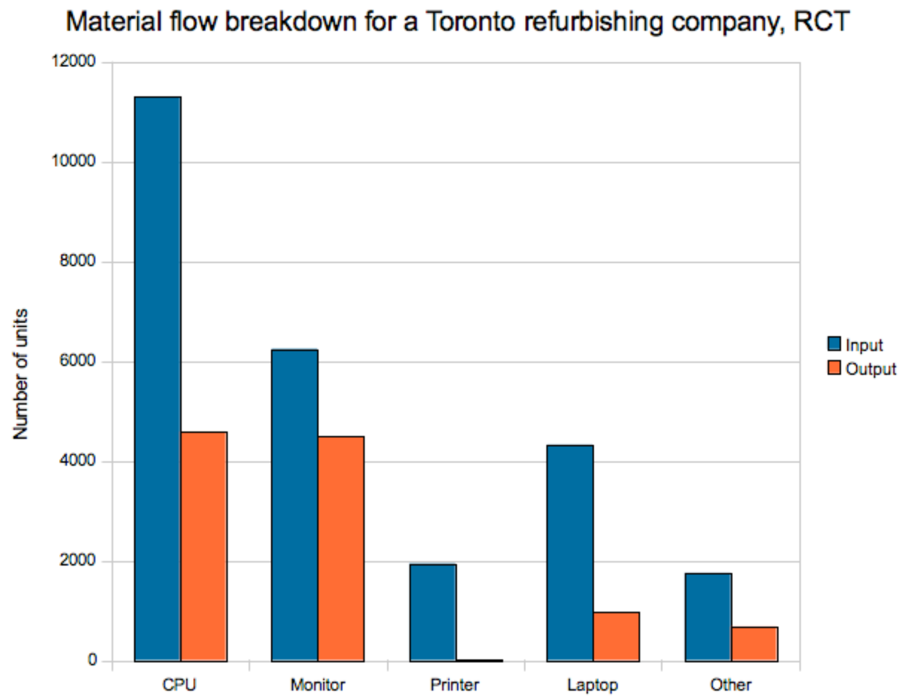


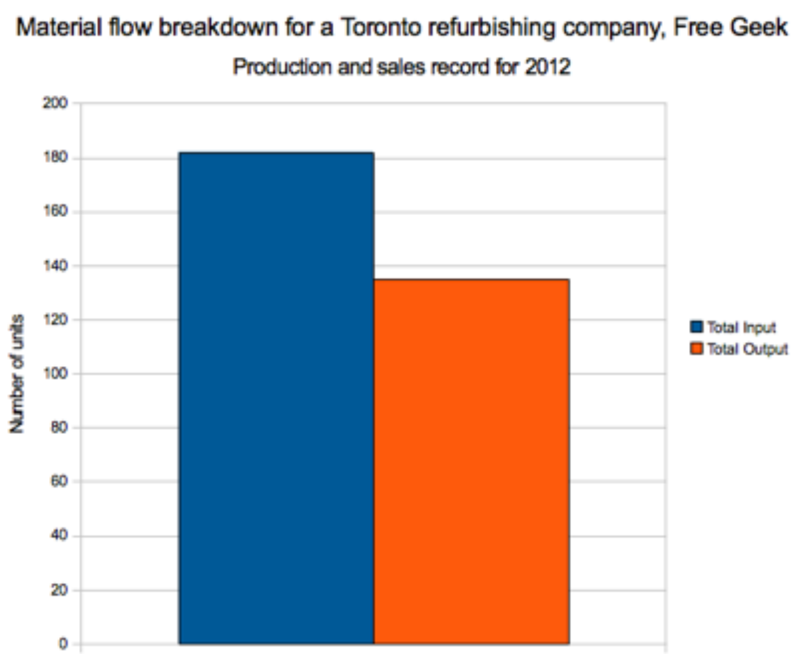
Figure 4.9 Total length of time spent at the Toronto refurbishing centres by volunteers and staff in 2013



In general, it can be concluded that a large part of the economic sustainability of non-profit refurbishing depends on the steady inflow and outflow of material. It is important to point out, that the input of electronics for refurbishing companies is more fragile than for their recycling counterparts. The quantity of electronic parts that are lost to breakage or age play a big part in this instability. The refurbishing centres have to rely on only a portion of their total input to provide them with enough material for refurbishing. The rest is often lost to recycling. This pattern is apparent in each non-profit centre's annual breakdown of inputs and outputs (Figure 4.10). Figure 4.10 compares the actual input of the total material for both centres with the final output of refurbished electronics. The visible contrast suggests that a significant portion of the incoming materials do not meet the standards of the centres and thus are not refurbished. RCT receives a small monetary reimbursement from an OES processor who collects their electronics (Interviewee #3, May 28, 2013). At the same time, Free Geek pays a recycling company to collect the unused materials (Interviewee #16, July 9, 2013). Such arrangement unlikely contributes to the long-term economic sustainability of non-for-profit refurbishing.

Figure 4.10. Material flow breakdown (in terms of inputs and outputs) for the two Toronto refurbishing centres in 2012. Data is displayed in the number of units of electronic items.





All in all, the non-profit refurbishing sector relies on a number of crucial factors to maintain a sustainable level of operation. First and foremost, it is important to remember that neither of the Toronto based refurbishing centres are currently economically self-sufficient. The two non-profits are funded through several social service and employment support programs. In addition to the direct funding support, the enterprises also rely on free donations of electronics from the public or local commercial sector. They have to compete with the for-profit recyclers for the said material. The centres do provide unique technical training opportunities for the local residents. Yet, the success and usefulness of these programs strongly depend on the level of organization within the refurbishing companies. Lack of structure could in the end damage the centres ability to consistently process electronics. Overall, it seems that the sustainable existence of the non-profit sector strongly depends on the cooperation and support of other actors within the electronic waste management network. The enterprises could hardly survive without the sources of external funding; large body of volunteers; consistent supply of free, quality electronic material, and even the provision of recycling services by other electronic processors and OES. This final point was stressed by one of the long-term staff members at RCT. He explained that without the recycling services that OES is able to provide them with, their productivity would likely suffer.

> "To be honest, in [the] days, when I started working here, we used to take each printer/ computer and dismantle it. You can imagine, how much work that would be. We had maybe 3 tables down here and boxes, boxes with plastic, metal etc. We would separate and sort everything ourselves. But it would take so much time. You try to do it fast too, because you have lots of stuff. Now it is easier with OES,

they pick up the skids and the next day they are here". - Interviewee #6, personal communication, May 28, 2013

The above description is well in line with our previous theoretical discussion of sustainability and co- operation between multiple actors in the electronic waste management system (Please refer to Chapter 2). Based on my fieldwork analysis, non-profit electronic refurbishing is unlikely to survive without the collaboration with other actors within the waste management sector. The various skills and services that the multiple involved organizations provide, can enable the success of a relatively difficult task of electronic refurbishing. This point stresses the importance of development of a variety of different organizations (large –scale mechanical; small-scale manual; and even non-for-profit refurbishers) within the electronic waste management network. This discussion will be developed further in the following Chapters.

4.3 Conclusion

The provincial electronic waste management program involves the cooperation and balance of a number of different actors and aspects of electronic processing. At first, it appears that the overarching Ontario Electronic Stewardship has the strongest influence on the shape of the electronic waste processing system in Toronto. In fact, OES does have the ability to influence the distribution of materials between different processors, prioritize electronic recycling over refurbishing and designate certain items for processing while leaving the others. Yet, the roles within the system cannot be attributed to only one actor with such certainty. A further examination of the functionality of the daily electronic processing and non- profit refurbishing adds obscurity to the above picture. It appears that the actual execution of electronic refurbishing efforts is quite complex. Firstly, the market for second-hand electronics is diminishing. This phenomenon can be likely attributed to consumer behaviour that is driven by product obsolescence (Chapter 7). As a result, for-profit electronic refurbishing may soon become economically unsustainable. Local refurbishing efforts have the capacity to encourage the development of several social and environmental factors of sustainability. At the same time, the non-profit electronic refurbishing requires the commitment from other actors within the network, including OES. Consequently, it appears that the current electronic waste management system in Toronto is not dictated by a single actor. It is a product of the actions of a number of different stakeholders within the system. It is shaped by many different economic, environmental and social factors. The role of the municipal government and other local actors will be further discussed in Chapter 5.

Chapter 5: Municipal electronic waste management

5.1 Overview of municipal e-waste management

The City of Toronto Waste Management department oversees municipal electronic waste management in the research area. The City's program is relatively unique. The City of Toronto is one of the few municipalities that provides curbside collection and drop-off services for electronic waste. Their detailed electronic waste management program is intended to provide equal access to sustainable waste disposal for all of the City's residents. The fieldwork results, however, have revealed a number of limitations to the City's current management program.

The provincial electronic waste management system, described in Chapter 4, has a degree of influence over the local regulation of electronic processing. As described previously, the provincial program, does affect the types of electronic items that are being collected locally. Additionally, the OES program, along with the local electronic processors, influences the allocation of the e-waste to recycling or refurbishing. As it will be portrayed in this Chapter, the City's scope of e-waste management cannot largely influence the above factors. However, the formal municipal e-waste program does have the capacity to impact other factors of local sustainability.

Multiple aspects of the local electronic waste processing system are influenced by the decisions that are made on a local municipal scale. The City's role as a regulator gives it an opportunity to restrict access to electronic waste collection to only a certain group of actors. Additionally, the City currently indirectly limits its collection and drop-off services to only a portion of the local residents**.** The City's program is restricting the magnitude of the ‘sustainable’ e-waste management services to only the certain parts of the urban area. The following sections will describe the characteristics of the current electronic waste management system in the Toronto CMA in more detail. Their effect on the sustainability of the overall e-waste management will be discussed.

5.2 The scope of the municipal collection and drop-off services for local electronic waste

The City of Toronto has its own electronic waste management program which focuses on the municipal diversion goals. The electronic waste is collected through several different sources. The various collection methods can be broken down into three categories: the curbside electronic collection; Community Environment Days collection events, and Drop-off centres located around the City. Through these different collection methods the City is able to divert a relatively large quantity of electronics. The amount of collected materials has slowly increased over the years. Based on their official processor’s (a private large-scale recycling organization) weight collection reports, the City was able to divert 1719 tonnes of residential electronic waste from the landfill in 2011 (City of Toronto, 2013; Interviewee #1, December 15, 2012). The total diversion for 2012 can be estimated at 2000 tonnes (Interviewee #1, December 15, 2012; Interview #19, August 12, 2013).

The three main electronic waste collection programs are expected to provide sufficient services for the majority of the City’s residents. Yet, the detailed examination of the collection events has revealed potential shortcomings of the program. According to the fieldwork results, the City’s current electronic collection program is <u>limited to only a portion of its current residents.</u> As a result, the City is currently <u>unable to collect a significant quantity of the available residential electronic waste</u>. The origin of these shortcomings is described through the fieldwork evaluation of the collection services.

5.2.1 The curbside electronic waste collection

The City of Toronto provides a curbside collection of electronic waste as a part of its regular waste pick-up and recycling services. The program has unofficially been a part of the regular curbside collection for a number of years. It was in 2010, however, when the City officially added electronic waste collection to the list of its services (Interviewee #20, August 12, 2013). Since then, the program has received more publicity through the City's advertising campaigns.

The electronic waste curbside program follows the recognizable pattern of regular waste collection. At the designated times of the day and week the residents are encouraged to put out their electronic waste along with their regular garbage and recycling items at the curbside, in-front of their place of residence (Image 5.1). At the time of collection, the City trucks pick-up old electronics from the residential areas. The city does have special trucks that are able to collect bulkier electronic items. However, most often the curbside electronics are consolidated into the regular collection truck's side compartment. The City also provides special bags for the collection of smaller, miscellaneous electronic items. Once the items are collected, they are taken to the City's 'Reuse' centre (described in detail below). At the centre, the items are consolidated and picked up by the City's single electronic waste processor (Interviewee #19, August 12, 2013).

Image 5.1 Electronics deposited for curbside collection in Toronto

The above-described curbside collection process has one main restriction. It is currently limited to the residents of houses or small-apartment building with access to a curb (City of Toronto, 2014). The residents of larger apartment buildings or houses without direct curbside collection are expected to find other means for disposal of their electronic waste. Consequently, this convenient method of disposal is not available to some of the City's residents. The other two collection programs are expected to address this shortcoming. However, in some cases, other methods of e-waste disposal are not accessible to these residents either.

5.2.2 Drop-off centres for the electronic waste

The City of Toronto manages seven drop-off depots that provide residents with the means for disposal of 'specialty' wastes. The depots are distributed evenly throughout the city. They serve as drop-off locations for a number of waste items including paint, household hazardous waste, and electronics (City of Toronto, 2014a; Interviewee #19, August 12, 2013). Each depot has a particular set of procedures for the sorting and shipping of electrical and electronic waste. Fieldwork examination of one of the centres provides insight into these procedures.

The majority of the electronics dropped-off at the centre can be classified as personal, household electronics. A large proportion of the material encountered during the site visit included household and kitchen appliances, personal IT devices (laptops, monitors and computer peripherals) and audio-video devices (DVD and Blueray players) (Image 5.2). The electronic waste drop-off area is situated right by the entrance of the visited drop-off site (Image 5.2). The waste is kept in an individual 20' walk-in bin. The drop-off process is supervised by one or two City employees. The staff receives the dropped-off electronics from the residents who drive into the area. Once received, the electronics are placed into individual containers inside the walk-in bin. Once the bin is full (approximately every two weeks), it is picked up by the City's designated electronic waste processor.

The main limitation to the residents' ability to dispose of electronics via the drop-off centres is access to a vehicle. While the drop-off centres are located throughout the city, their physical locations are often difficult to access via public transit. At the same time, the bulky appearance and relatively heavy weight of some of electronic devices (CPUs, monitors, TVs) is likely to deter a resident from an attempt to reach one of the drop-off centres without a car. Therefore, while these centres do provide a convenient opportunity for electronic waste disposal, they are limited to the residents who have access to a car. The final collection program is expected to address this restriction of the e-waste drop-off.

Image 5.2 Toronto drop-off centre for electronic waste

5.2.3 Community Environment Days

The City's Community Environment Days provide another opportunity for the residents to dispose of their excess items (Interviewee # 19, August 8, 2013). City of Toronto departments, including Waste Management Services, organize the events. A number of different organizations are usually present at the events. An environmental consulting company provides a drop-off for Hazardous Household Waste (HHW) and tires. Toronto Waste Management sets-up information booths as well as a free electronic waste drop-off. A few local charities accept a variety of items such as clothing, furniture, and even second-hand electronics (Personal observations during site visit, September 7th, 2013). The events are intended to serve the residents in individual neighbourhoods around Toronto. They are usually set-up for one day in a publicly accessible location within the neighbourhood (Image 5.3). In 2013, the City held 45 individual Community Environment Days at different Toronto neighbourhoods (City of Toronto, 2014b).

The Community Environmental Days are designed to provide a convenient material disposal service to the neighbourhood residents (Interviewee # 19, August 8, 2013; City of Toronto, 2014b). In theory, the event's multiple locations should enable all residents, who do not receive curbside pick-up, to rid themselves of unwanted items without having to drive to one of the drop-off centres. Yet, the fieldwork data collection during one of the events provided contrasting observations. All of the used electronics collected at the event were dropped-off via a car (the items filled up approximately one half of a walk-in shipping container; Image 5.3). This observation brings up the potential question of the real accessibility of the electronic waste collection to the majority of the urban residents. It seems that even the services at the locally organized community events are not fully accessible to a portion of the population.

Image 5.3 Electronic waste collection at the Community Environment Day

The fieldwork observations suggest that a portion of the city's population is not being serviced by the City's formal e-waste collection. A number of factors result in these consequences. From personal experience, it can be concluded that a predominant portion of electronic devices are quite heavy. While this picture has begun to change with the newer personal electronic devices striving for the thin and fashionable look, these newer devices are not yet present, to a significant degree, amongst the discarded electronics. The majority of residents are thus confronted with the issue of ridding themselves of their old, bulky and relatively heavy electronics.

As mentioned previously, the current curbside collection does not extend to the residents of large apartment buildings and houses without an access to a curb. Thus, these residents are limited to using the drop-off centres or Community Environmental Events to dispose of their e-waste. While the Community Events are designed to limit the residents' necessity for a vehicle, fieldwork observations have proven an opposite point. For the fortunate car owners, either of the above options may require little effort. The same cannot be said for the large portion of the Toronto public that does not own a vehicle. A city the size of Toronto can be expected to contain a large portion of the population that relies on public transportation. According to the 2011 Census, roughly 24% of Toronto residents have reported relying on public transit as a main source of transportation. This value provides an idea of the portion of the population that would find it more difficult to reach the drop-off locations and drop-off events (Statistics Canada, 2011). The combination of the above facts suggests that Community Environment Days, drop-off centres and curbside electronic waste pick-up are currently not servicing a significant portion of the population. The City's inability to collect a potentially large quantity of the available e-waste can have a number of negative economic, environmental and social consequences.

5.3 Limitations of the municipal electronic waste management system

The current electronic waste collection program in Toronto has an opportunity to promote the sustainability of e-waste processing on a local level. However, a number of factors are limiting that ability. The provincial regulation of e-waste management has its effects on the municipal diversion of electronics. The City is relatively powerless in its ability to influence the types of electronics that are processed by the electronic recyclers (Chapter 4). Similarly, the state of the refurbishing and reuse market is beyond the control of the municipal e-waste management (Chapter 4). At the same time, the City is responsible to ensure the local sustainability of the e-waste collection services. Currently, the three collection programs are exclusive to only a portion of the residents of Toronto. The scope of the program must be extended to ensure the collection of most of the available e-waste in the urban area.

First and foremost, as described in Chapter 4, the current collection of electronics excludes a number of categories of electronic waste (Section 4.2.2). It has been determined however, that this prioritization of the types of electronics has been shaped by a number of external factors. Some of determining factors include the regulation written by the MOE and the economic feasibility of processing low precious- material content electronics etc. (Chapters 2 and 4; Huisman, 2003; Hageluken, 2006). As a result, the decision behind acceptance of the certain electronics for recycling is currently beyond the scope of the municipal government.

Secondly, the focus of the local e-waste management program lies mainly in electronic recycling, with refurbishing and reuse efforts not being actively promoted. The City of Toronto does advertise the options for donation and re-use of electronics locally on its website. Yet, the program's commitment to reuse and refurbishing is limited by the availability of such services. As mentioned in Chapter 4, refurbishing and reuse of end-of-life electronics are restricted by the their economic efficiency. As a result, many electronic processors in Toronto do not participate in electronic refurbishing. The Toronto CMA hosts only two non-profit companies that accept electronics for refurbishing (RCT and Free Geek, discussed in Chapter 4). Both of these companies are specifically mentioned on the City of Toronto 'Re-use It' webpage (City of Toronto, 2104c). Yet, the current and future processing capacity of the non-profit refurbishing sector is uncertain. Without the expansion of the local refurbishing market, the City of Toronto's promotion of local refurbishing will unlikely yield a significant change in the e-waste processing system.

It could be argued however, that the City should focus on promoting local reuse of electronics between residents and local charities. Such effort has already been attempted by the Waste Management Department. The City of Toronto consolidates its collected curbside electronics (and other specialty waste items such as mattresses, toilets and furniture) in one large facility – the Cherry Street Re-use centre. Currently, the electronics are stored at the centre prior to their direct shipment to the designated electronic recycler. Yet, that was not the original designation of the facility. According to one of the participants of the study (Interviewee #20, August 12, 2013), the centre was initially designed as a Re-use facility (hence its official title). However, its role changed over time due to the lack of enthusiasm from the community and the feasibility of the re-use of the majority of the items that have been collected.

> “Originally ... we were going to work with some local charities and have them pick-up the items directly from here. That has not worked as intended. First, I think many charities just did not know about our services. Also, unfortunately, many of the items that we are receiving are not, what you would call reusable ... We did have a few things that we have put aside for some charities and they have come to sort through it. But on more than a few occasions they have simply rejected most of the items. So it has just become more of a recycling place” - Interviewee #20, August 12, 2013

As a result, the Re-use centre has morphed into a 'Recycling centre' over the years. Needless to say, the City of Toronto has since curbed its enthusiasm for the long-term storage of potentially reusable items. While this type of reuse efforts may demonstrate a potential at first, the realities of refurbishing and repurposing of old items has on a number of occasions dampened their success (Macbride, 2011). This suggests that the City’s ability to promote electronic refurbishing and reuse is limited by external factors.

While the local electronic waste management program cannot directly address the above factors, it can promote other aspects of sustainability. Based on the results of Households and Environment Survey, discussed in detail in Section 2.3, 46% of residents do have electronics that require disposal. Only half of the electronics are disposed through the ‘formal’ collection method, while a quarter of them are simply stored (or ‘hoarded’) at home (Statistics Canada, 2011). Such statistics suggest that a) a large portion of the

Toronto residents need an access to easy disposal of their electronics b) the City of Toronto may be omitting a potentially large quantity of the available electronic waste from its formal collection efforts.

The above evaluation of the current municipal electronic waste management system points to several aspects of sustainability that are not being addressed by a municipal system. The provision of equal services to all residents has been highlighted as one of the key factors of sustainable communities (O.D.P.M, 2005). The City of Toronto's inability to provide equal electronic waste collection services to all of its citizens is not meeting the above expectations. The official system seems to lack understanding of the broad range of the participants, activities and the materials that could be actively present within the system. It could be argued that the City's program may benefit from additional knowledge of the vernacular (local, informal system that has not been accounted for in the official planning) order of waste management that has been established by non-official actors in Toronto (Scott, 2012; Chapter 7). In the mean time, the City's current official collection program is partially impairing Toronto's ability to develop a sustainable urban community.

The City's omission of a potentially large portion of residential e-waste can damage the economic sustainability of the overall collection program. The physical process of collection of waste bears high financial costs to the municipality (Ackerman, 1997; Macbride 2011). Electronic waste, being an economically valuable resource (Section 2.4), has the potential to alleviate those costs for the City. The City's ability to access the large portion of available e-waste can act as a limiting factor for the long-term continuation of its services. In fact, the City seems to be aware of this problem. They currently concentrate their efforts on limiting other informal collectors ability to 'steal' the e-waste from them.

5.4 Informal electronic processors and the City

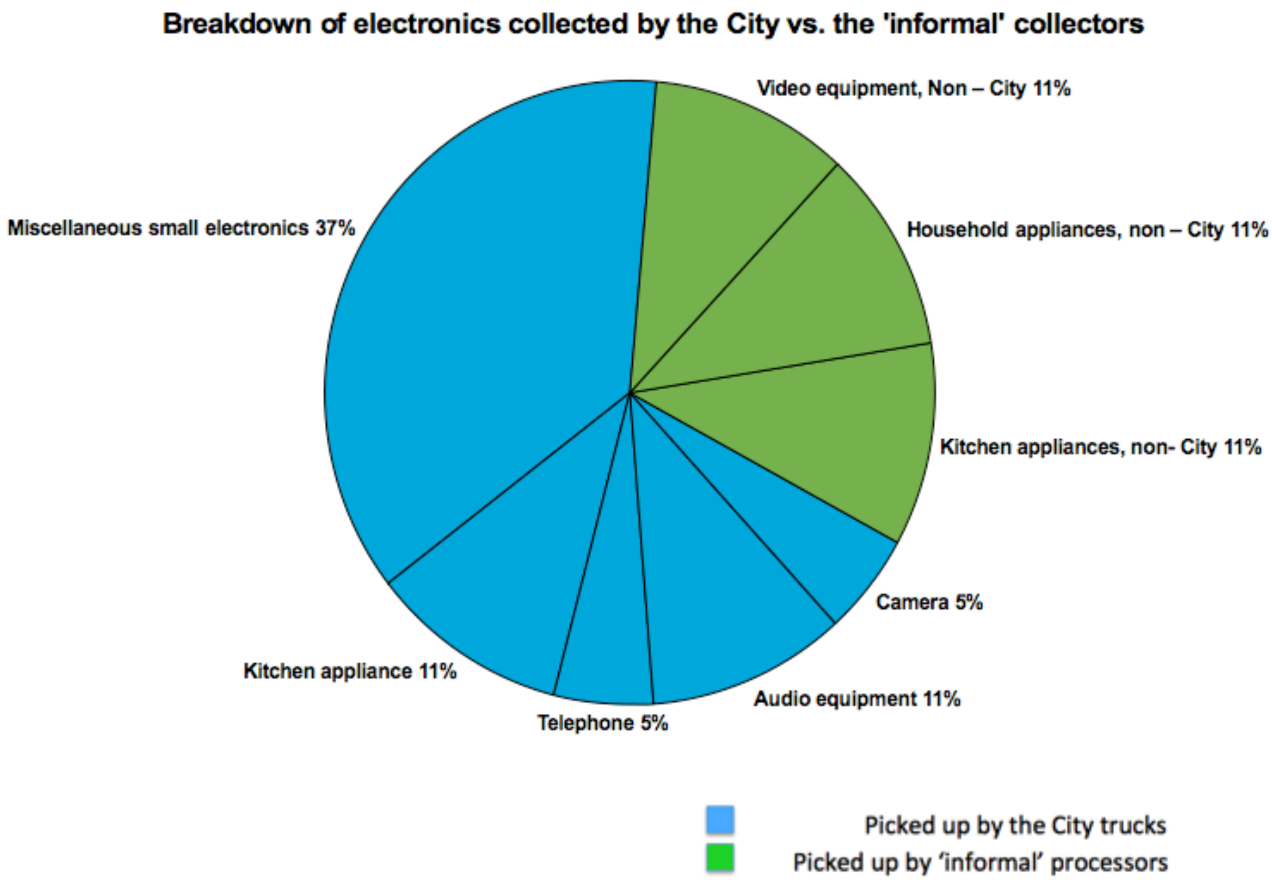
The current pattern of the City's of Toronto curbside collection allows for potential loss of some recyclable materials. The City appears to be in competition with the informal electronic waste collectors and processors. This group of e-waste recyclers and refurbishers arguably occupies the most obscure section of the local e-waste market. Their presence has a number of positive and negative effects on the sustainability of the local e-waste management program. The quantity of material collected by the informal sector affects the economic sustainability of the formal City collection. On the other hand, the participation in such scavenging activities could contribute to the redistribution and local reuse of the electronics, thus avoiding the mechanized recycling process. Both of these factors currently add to the tension between the City's collection program and the individuals interested in refurbishing and reuse of electronics. This relationship is a perfect example of the real life complications preventing the development of the theoretical 'sustainable' management system. The details of the complicated characteristics are described in this section.

Both the City of Toronto Waste Management department and OES are aware of the toll that informal scavenging takes on their overall e-waste collection. Yet, the volume of the 'lost' material is not measured. A part of the fieldwork data collection thus concentrated on comparing the actual amount of e-waste items collected by the City's trucks to the items that were collected by other actors.

The City of Toronto's garbage collection is most often scheduled for the early hours of the morning. The residents are thus encouraged to put out their garbage for collection early in the morning or late at night. The time spanning between the deposition of the garbage onto the curb and its collection by the City employees often provides an opportunity for 'scavenging'. It was during this time, when the researcher chose to collect most of the data by ‘garbage-gazing’ (Chapter 3). The data collection provided an estimate of the quantity of electronics that are being taken prior to the formal curbside collection as well as evidence of the actual presence of informal e-waste processors.

Information on the quantity and quality of electronics deposited for City curbside collection was gained by exploring the curbs of the local Toronto neighborhood (Chapter 3). A portion of the data collection provided an approximation of the total quantity of e-waste that is ‘lost’ to informal collection efforts. The electronic materials found on curbside in August and September (Figure 5.1) were separated into the categories that were successfully picked-up by the City trucks and those that disappeared before the morning collection. The results showed that over 30% of the sample did not make it to the City collection. It is likely that the 'missing items' were instead collected by the informal collectors and in some cases the residents of the neighbourhood. The 'lost' items mainly fell into the video equipment, household appliances and kitchen appliances categories (Figure 5.1). Although the sample size for this particular measurement is relatively small (See Chapter 3), the breakdown does provide an estimate of the quantity of materials ‘lost’ to the City. It is also possible that an additional portion of other valuable items is not captured in the sample. Some materials may have been collected even prior to the designated sampling time. This hypothesis was supported by a chance encounter with one of the local informal electronic collectors.

Figure 5.1 Curbside electronic collected by the City of Toronto vs. informal recyclers. Percentages are based on number of units for each category divided by the total number of electronics.



A brief interview with an informal electronic waste recycler highlights some characteristics of the informal sector of waste management. The researcher was able to interact with an individual who was collecting curbside e-waste as early as 38 hours before the time of the City Collection. The recycler claimed to be collecting a "truck-full" (approximately 800 pounds) of curbside electronic material on weekly or by-monthly basis (Interviewee #22, August 20, 2013). If extrapolated to a year, this sole informal collector could be responsible for the 'disappearance' of nearly 20 tonnes of electronics. The combined efforts of the various informal collectors could thus amount to a large quantity of electronics. Surprisingly, the state of the situation as it appears right now is not overly disconcerting to some of the City Waste department's employees:

> "Well yes... we are making less money now for sure than before. But at the same time, I am not too concerned. If those other guys know what they doing and can fix things up, that's ok too I guess." - Interviewee #20, August 12, 2013

While certainly not all of the City's municipal employees hold to the above opinion, the above quote does align with the social sustainability ideas discussed in Chapter 2. In accordance with the ideals of a 'sustainable community', no resident should be excluded from the economic, social or political participation in his or her community (Dempsey et al, 2011). While the above volume of the e-waste could contribute to the further economic stability of the formal collection program, it can certainly benefit the informal scavengers as well. It can provide an opportunity for the local reuse of electronics prior to their recycling. Additionally, it may supply a necessary source of technical training (through manual refurbishing) as well as potential profit (from local refurbishing and reuse) to the local residents. Thus, supporting the informal e-waste collection efforts could further individuals' ability to participate in the development of sustainable local communities.

The informal sector's ability to contribute to the reuse and refurbishing of electronics is partially unveiled in the brief interview with the informal collector. The participant's minimal English skills did restrict the amount of information collected during the encounter. However, the processor claimed to be concentrating his efforts on refurbishing the electronics and selling them online. The parts that were broken or not useful were stated to be sold or thrown out (Interviewee #22, August 20, 2013). This particular collector seemed to have developed a small business model with his relative. The two men visited various Toronto neighbourhoods at night. The collected electronic waste was then processed at their place of residence or a small home-office (unclear in the interview). It is unknown, however, what part of the collected electronics were successfully sold online (i.e. Re-used) and which were broken down into parts. The actual disposal of the un-used electronic parts could constitute a problem for the environmental sustainability of e-waste management. It is uncertain whether the informal processor relies on some of the City's formal e-waste collection services. If not, it could be speculated that some of the e-waste parts end up in landfill.

While the actual recycling practices developed by the above informal processor are unclear, the disposal techniques practiced by a few other informal collectors were established during fieldwork. A number of the members/ volunteers at the non-profit refurbishing facility in Toronto identified themselves as informal scavengers as well. These individuals describe collecting electronics "off-the streets in the nice neighborhoods" (Interviewee #11, June 12, 2013). They then refurbish the found electronics (mostly computers or laptops) in their homes or (more commonly) bring them to the non-profit centre and fixed them there. Once fixed, the electronic are sold (or often given away for free) to the scavengers' friends, family or clients of the centre. This peculiar pattern of local redistribution of e-waste exposes the different possibilities for the e-waste management system. This type of a commitment to the reallocation and sustainable management of the electronic waste resources can hardly be ignored by the municipal government.

Informal electronic sector has a potential to address several factors of sustainable local e-waste management. While the appropriation of the curbside electronics by the informal processors from the City's formal collection could negatively affect the economic sustainability of the 'formal' services, it has a greater potential to address other local environmental and social factors. From the environmental perspective, direct reuse and refurbishing of electronics by informal processors could provide a second life for the electronics, thus alleviating the high-energy costs of electronic production (Williams et al, 2008). The local reuse of e-waste can also help redistribute necessary electronic items to local residents in need.

Additionally, the informal activities add a necessary level of disorder to the seemingly ordered, official waste management system. Although the 'disruption' of the City's official collection process may seem as a negative attribute at first, it has its benefits. As demonstrated above, the City's e-waste management program does not provide an opportunity for a) classification of e-waste into useful (items that can be re-used) and non-useful items b) testing of the functionality of the devices c) re-use of the devices. On the other hand, the above three activities are the specialization of the informal waste processors. As a result, the informal system can be recognized for its ability to correct the shortcoming of the City's program by adding a little 'disorder' (More on this in Chapter 6 and 7). An ordered and singularly controlled management system has often resulted in unsatisfying societal outcomes, in the past (Scott, 2012). The promotion of alliances between the seemingly opposite actors within the network can promote the necessary level of diversity that is needed for a sustainable management system.

The above factors demonstrate the capacity of informal collection to affect the local sustainability of e-waste management. Finally, according to the Bruntland report, 'sustainable development' of cities depends on "the close work with the majorities of urban poor … and those in the informal sector … who are the true city builders" (W.C.E.D, 1987). Consequently, the promotion of informal e-waste management should trump the pure economic benefit to the City's formal collection program.

5.5 Conclusion

The municipal electronic waste management system in Toronto is influenced by a number of factors. Several aspects of the provincial e-waste regulatory system contribute to the state of local e-waste management. The allocation of electronic items for the formal collection is determined by the MOE, OES and the actions of the local e-waste processors. Similarly, the commitment to e-waste refurbishing over recycling is dictated by external economic factors. As a result, the municipal program cannot directly address the above two factors. At the same time, the City's e-waste management can be locally modified to encompass a larger portion of the urban population and their electronic waste. Currently, the three of the City's formal collection efforts (curbside, drop-off centres and community events) are omitting a potentially significant portion of the available urban e-waste. The reasons for this exclusion can be drawn from the actual scope of the City's official program as well as the ongoing competition for material with the informal sector.

The informal sector plays a complicated role within the sustainability of the local e-waste management system. From the point of view of the formal collection, the scavengers are damaging the economic efficiency of the management program. On the other hand, the informal market demonstrates a potential to address other social and environmental factors. The informal system contributes a necessary level of disorder to the official system, thus correcting for its shortcomings.[14] The direct redistribution of reusable e-waste benefits the part of the community that cannot otherwise afford new electronics. Through these activities, local refurbishing and reuse can alleviate the high-energy costs of electronic production.

It is important to note that the reuse sector does not have the capacity to replace large-scale recycling and vice versa. As mentioned previously, each one of these management sectors occupies a specific niche in the overall process of sustainable waste management. However, the above-described characteristics of the reuse sector definitely solidifies the conclusion that an electronic waste management system that will include a significant collaboration between the large-scale and informal recycling sectors will prove to be most optimal from the economic, social and environmental sustainability perspective for the development of a city.

The examination of the municipal e-waste management program portrays the complex circumstances within which the 'ideal' image of sustainability should be achieved. Based on our findings from Chapter 4 and 5, each actor within the e-waste management system has its own set of positive and negative characteristics. Moreover, it appears that a complex process of harmonization of the above characteristics has shaped the existing electronic waste management system. As such, the modification of any current factors within the established system could be a long and difficult process. Harvesting the talents of each individual actor and promoting multi-sector alliances can prove to be the force behind the necessary change towards sustainability.

[14] To be discussed in more detail in Chapter 7

Chapter 6: Results

Network Analysis and Sustainability of the Electronic Waste Management System

6.1 Introduction

As shown in Chapters 4 and 5, the Toronto Central Metropolitan Area hosts a multi-layered system for electronic waste management. The Toronto based sector includes an array of government, private and non-profit enterprises that contribute differently to the overall system. The provincial and municipal government supervises the top-down regulation of electronic waste management. At the same time, the private recycling and refurbishing companies occupy a large portion of the market. Finally, the non-profit refurbishing and informal processors exist within their own specialized niche. All of these efforts have created a relatively complex series of networks. Yet, their long-term sustainability is uncertain. This Chapter will focus on the sustainability analysis of the existing networks within the electronic waste management system in Toronto.

The fieldwork based in the Central Metropolitan Area of Toronto has revealed the complicated structure of networks within the electronic waste management system. The purpose behind the field research was to analyze the current and future potential for the sustainable development of the management sector in an urban area. While Chapters 4 and 5 summarize the general functionality of the sector as it appears right now, Chapter 6 will carry the analysis further. The overall mechanics of the electronic waste management system will be visualized in two networks. The structure of the interactions and material flow within the area will be analyzed. The theoretical image of sustainability (Chapter 2) will be applied to the fieldwork results. The Chapter will thus draw conclusions on the current state of sustainability of the electronic waste management system. Recommendations for the enhancement or modification of certain aspects of the system will be provided.

6.2 Network analysis through visualization

The previous Chapters describe the variety of actors and their roles within the electronic waste management sector in Toronto. The variability of activities performed by each participant indicates the complexity of the existing system. At first glance, the combination of the electronic waste processing efforts appears to address a number of the necessary aspects of sustainability. Yet, some key attributes of sustainability are harder to identify. The literature suggests that long-term sustainability is primarily supported by the creation of stronger alliances between different actors within the management network (Baud et al, 2001; Gutberlet, 2010). Hence, the following sections will focus on the description of different interactions within the electronic waste management network in Toronto. The Network Analysis methodology will be used to provide a visual depiction of a complex network.

Typically, Social Network Analysis methodology concentrates on capturing solely the 'social' relationships (i.e. individual interactions) within a network. In our case, however, the social relationships will be complemented by a visual summary of the material flow between individuals and organizations. The social interactions within the network will be visualized in a "Collaboration Network". The material flow analysis will be depicted in "Material Flow Networks". These illustrations will describe the relationships formed between organizations within the network. This knowledge will have broader benefit to our understanding of sustainable waste management in an urban setting.

6.2.1 Collaboration network

As demonstrated in Chapter 4, the current electronic waste management system in the Toronto Census Metropolitan Area involves a large number of different actors.[15] The system has an even greater number of different relationships between actors. While some of the interactions are obvious, others are more obscure. Naturally, the knowledge of these interactions is key to understanding the e-waste system as a whole. As such, it was the intention of the researcher to discover collaborations (social relationships) between key actors within the electronic waste management sector. A combination of information collected during in-person interviews, phone interviews, participant observation and online research, yielded the following "Collaboration Network" of the electronic waste management system in the Toronto CMA (Figure 6.1).

Prior to continuing the data analysis and discussion, some useful terminology must be defined. First and foremost, the term collaborator was borrowed from the Vance-Borland

[15] The scope of the fieldwork covered 2 government-related organizations (OES and City of Toronto); 7 electronic waste processors and nearly 50 other organizations that served as the source of the material; source for the regulations and downstream processors of the electronic waste.

and Holley study (2011) (described in Chapter 3). In their network analysis of environmental stakeholders, the authors referred to any relationship between individuals that has formed within the context of a certain project as collaboration. A similar interpretation of a collaborator was adopted in my SNA questionnaire (Appendix I). Study participants were asked to "list the organizations or individuals … that you collaborate with while managing electronic waste". A collaboration was defined as "any kind of an interaction inside and outside of the work setting that relates to electronic waste management." The participants were also asked to define the type of collaboration with each identified actor (e.g. source of regulations, downstream processor etc.). This information was then used to construct the visual network shown in Figure 6.1.

However, the presence of collaboration does not necessarily indicate the presence of an alliance within the network. An alliance is defined as an "established relationship [partnership] between actors within the sector" (Baud et al, 2001). In their study on the alliances within the solid-waste management sector in several developing countries, Baud and colleagues identified the key characteristics of an alliance. An alliance is a mutually beneficial relationship between two or more actors that is enduring over time. This distinction between a simple collaboration and an alliance is key to the context of long-term sustainability that I have discussed throughout this thesis. It is through the creation of these types of alliances that the ideal goals of sustainability (Chapter 2 and 3) can be addressed. It was the original intention of the Network Analysis to answer the primary research question: What is the overall structure of social alliances in electronic waste management system in Toronto? However, the Network Analysis methodology was unable to distinguish between collaboration and an alliance (as defined above).

This shortcoming of the characterization of social relationships was a result of the initial questionnaire design as well as the hesitation of the participants to reveal certain information. As previously mentioned, the questionnaire was modeled after the Vance-Borland and Holley (2011) study and thus was better suited to identify general collaborations between actors, rather than in-depth information on type and duration of relationships. In reality, a modification of the phrasing of the questions by the researcher could have prevented the characterization problem. Additionally, even though the researcher did attempt to prompt the participants to indicate the type of collaboration with other actors (Appendix I, SNA Questionnaire, Question 5), few chose to provide that information. As mentioned in Chapter 3, a number of the participants were hesitant to reveal the names of the actors that they collaborate with, as well as further detail on their relationship. This lack of information forced the researcher to complement the SNA data with the information found online. This modified methodology did assist in the final creation of a "Collaboration Network". Yet, without the in-depth information on the longevity and type of relationship between the majority of the actors, the network diagram was unable to distinguish alliance from general collaborations.

The analysis was nevertheless useful in providing a basic visual overview of the participants and collaborations within the network. The overall network of collaborators, which still provides useful understanding of the key actors within Toronto, was depicted successfully (Figure 6.1). Nonetheless, it can only be used as a general outline of the relationships within the network, and not an indication of long-term alliances. The more in-depth understanding of key alliances was assisted through the information revealed through several personal interviews and qualitative data collection. This complementary information was successfully utilized to illustrate only a few of the key relationships with the network (Figure 6.2). They will be discussed in more detail below.

Figure 6.1 Collaboration Network: A visual representation of the various social relationships within the electronic waste management sector in the Toronto CMA. The actors are grouped by types of organizations. The size of the ‘nodes’ is proportional to the number of connections.

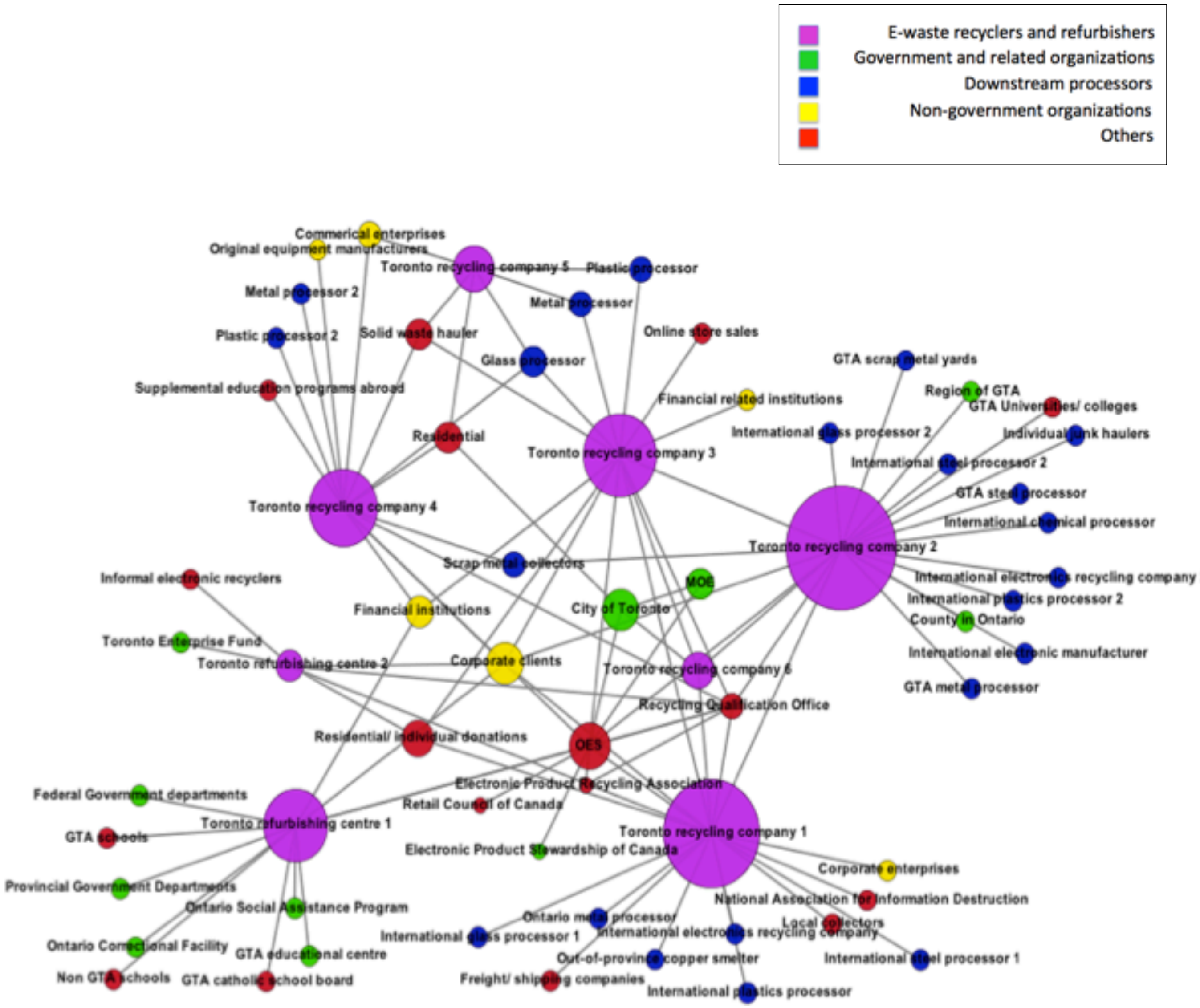


Figure 6.1 portrays the social networks within the electronic waste management sector in Toronto. The above image depicts all of the collaborations between the actors in the network who either participated in the study themselves or were indicated as a collaborator by one of the participants. Most of the key participants, such as government agencies and key sources of electronics, are present within the visualization. The only actors absent from the network diagram are the private electronic waste processors who were unwilling to participate in the research project and the informal collectors who were not encountered during the field research (Please Refer to section 3.2.3). All of the actors (nodes) are grouped into different types of organizations: Government (green); Recycling and Refurbishing companies (purple); Downstream processors (blue); Non-government organizations (yellow) and Others (red). The relationships, visualized by the links (edges) between the nodes, were created with the combined information from the Social Network Analysis Questionnaires as well as the information from interviews and organization's webpages. All the ties between actors are displayed as unidirectional.[16] The resulting network is depicted in Gephi.

In Social Network Analysis, great attention is paid to the actual structure of the network. The structural pattern of relationships within a network can have an effect on its functionality (information creation and diffusion; resolution of conflicts; policy output etc.) (Bodin and Crona, 2009). There are various characteristics that can be assessed for their role in the long-term mechanics of the network. Not all of these characteristics are applicable to this research project. The main limiting factor of my data analysis is the small

[16] Where the relationship can be assumed to flow in a single direction (i.e. OES regulates a processor or, processor is regulated by OES) a unidirectional tie can be recorded (Prell, 2011). In the case of this collaboration network, all actors displayed unidirectional ties.

scope of the research and the collected data. Nonetheless, there are several key factors portrayed in the above map that need to be addressed.

Degree centrality is a data measure that reflects the actors' level of activity within the network (Prell, 2011). By measuring the degree centrality, we can identify which actors have the most number of ties to other actors in the network. This characteristic can be theoretically related to the level of influence that a given actor holds (Prell, 2011). In our circumstances, the actors with the highest degree centrality may be able to influence decisions that are made in the electronic waste management network. The nodes for each individual actor in Figure 6.1 are scaled in proportion to their degree centrality. Through initial visual analysis, it can be deduced that the actors that may have a certain degree of influence on the network are the electronic waste Recycling and Refurbishing organizations. However, degree centrality is only a single type of quantitative Network Analysis measurement. It is limited in its ability to relay holistic information about the network. It does not take any other characteristics (such as the role of the actors within the network) into account. Consequently, while the large recycling/refurbishing organization are certainly able to contribute to the structure of e-waste management through their role in the industry, their identification as the key actors does differ from our previously developed dialogue in Chapters 4 and 5. This point is elaborated on further through data analysis below.

Table 6.1 The top 15 organization within the Collaboration network in electronic waste management in Toronto, sorted based on degree centrality.

Label	ORGtype	Degree centrality
Toronto recycling company 2	Recyclers	21
Toronto recycling company 1	Recyclers	18
Toronto recycling company 3	Recyclers	14
Toronto recycling company 4	Recyclers	13
Toronto refurbishing centre 1	Refurbisher	12
OES	Other[17]	11
Recycling Qualification Office	Other	8
Corporate clients	Corporations	6
Toronto recycling company 5	Recyclers	6
Toronto refurbishing centre 2	Refurbisher	6
City of Toronto	Government	5
Residential/ individual donations	Other	4
Toronto recycling company 6	Recyclers	4
Financial institutions	Corporations	3

To analyze the information provided by degree centrality measure further, Table 6.1 provides numerical breakdown of the collaborations for the top 15 actors. As visible in Table 6.1, the organizations displaying the highest degree centrality fall within the following categories: Recyclers/ Refurbishers (private and non-profit organizations

[17] The actual characterization of OES has been a cause of concern to the researcher. Theoretically, OES is identified as a non-profit organization. However, its complex relationship with government (MOE) and consumers (through eco-fees) was found not to be reflected through the simple characterization as a non-profit. In the end, the descriptor "Other" was selected as the most suitable Organization type for the Network Analysis.

specializing in electronic waste recycling or refurbishing), Government organizations (City of Toronto), Corporations (private organizations and institutions that are typically clients to the electronic refurbishing/ recycling companies) and Other (any other organization or individuals that participate in electronic waste management but do not fall within above categories). Based on the above results we can conclude that these organizations display the highest level of involvement or activity within our network (Prell, 2011). Nonetheless, the real life impact of each actor may not be portrayed through the above numerical data.

The number of connections that actors maintain is a measure of their ability to participate within the network. Higher degree centrality can likely benefit the actors and their cause. For example, by comparing the degree centrality of Toronto recycling company 2 (21 connections) and Toronto refurbishing centre 2 (6 connection) we can observe that the latter has significantly fewer collaborators within the network (Table 6.1). As such, Toronto recycling company 2 could benefit from the ability to share its opinions on the proper e-waste processing methodology to a much wider audience. This behavior could eventually result in further promotion of activities that support e-waste recycling. On the other hand, the Toronto refurbishing centre's network is not as widespread. The organization's level of involvement in the network could negatively affect the promotion of awareness about the benefits of refurbishing. At the same time, while the quantity of connection within the network is important, the quality of the connections is even more valuable.

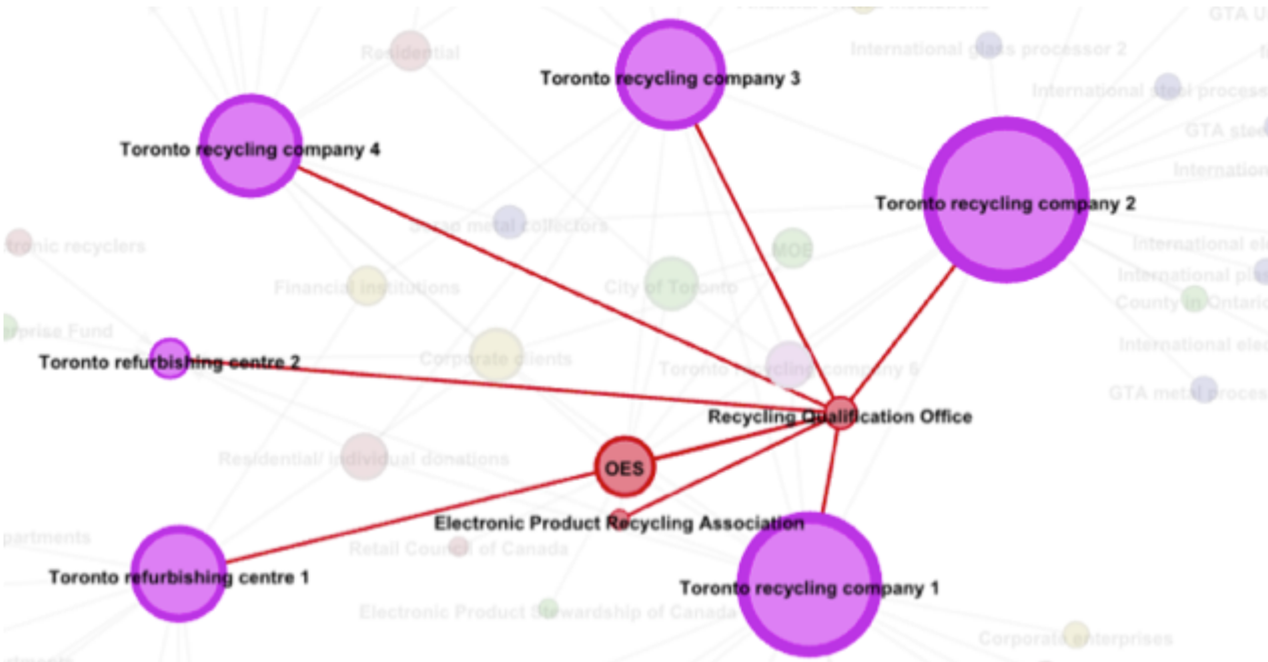
In reality, the number of connections portrayed through degree centrality may be unable to identify the true status of actors within the network. Following SNA theory logic, we could have concluded that the above list of 15 organizations holds the highest influence over the current e-waste management in the city (Table 6.1). The potential flaw of this list can be easily identified through the numerical status of the government and similar key organizations like the City of Toronto and OES. As is evident from the table, the large electronic recyclers represent the highest ranked organizations (Table 6.1). The reason behind such distribution is the amount of connections that were reported by each individual organization during the interviews. Since each recycling organization has a high number of regular interactions with various downstream processors, their total degree centrality is increased by these relationships. The Network Analysis was unable to account for the 'weight' of the actual role of each of the actors. While the number of connections that each private processor has within their own network is certainly important, it does not give them any legislative power (a characteristic that surely provides the ability to influence the current and future state of the network). In reality, as it was portrayed in Chapters 4 and 5, the actors holding the real influence through their alliances are OES, Recyclers Qualification Office, the City of Toronto and Ministry of the Environment.

As it is visible on the actual network illustrations (Figure 6.2 a, b, c and d), the above four organizations have ties to a number of equally influential actors, including each other. In theory, it is these types of alliance that may enable an organization to make decisions or change the outcome of decisions for the whole network. The alliances visualized for each of these key organizations have been compiled with a combination of SNA, personal interviews and research data. The combination of different information, revealed via multiple data collection methodologies, was able to highlight the most prominent alliances within the network. While they do successfully illustrate some of the key relationships within the network, they are still limited in their interpretation of the degree influence of each actor. For example, Figure 6.2a illustrates the general importance of Recycling Qualification Office within the network. The office audits each of the registered processors to ensure that they comply with established standards for recycling and refurbishing. The information that is not portrayed in the illustration, are the actors that establish the standards for the RQO (i.e. key industry members (electronic producers) that comprise the board of directors for the provincial electronic recycling programs) (RQO, 2014; OES, 2014a). These alliances with the industry leaders enable the organizations like RQO to influence the management of e-waste. Similarly, as described in Chapter 4 and illustrated in Figure 6.2b, OES's key alliance with the large-scale refurbishers, government and other associations enables it to influence the network from within. The City of Toronto's influence is hardly reflected through the collaboration network illustration (Figure 6.2c). The City's collection programs (Chapter 5) have an indirect affect on many actors within this network. Yet, their waste management programs are mainly executed by the Waste Management Department on its own. As a result, more obscure collaborations, like the one forming between the informal scavengers and the City (Chapter 5), are not visualized in the network. Finally, the Ministry of the Environment's presence within the network is hardly visible (Figure 6.2d). Nonetheless, this key government organization essentially dictates the regulation of e-waste within the whole province.

All in all, while the collaboration networks described in the above figures create a useful depiction of some of the relationships that occur with the network, they do not reflect the true influence that each actor holds within the network. The visual networks also lack the capacity to depict the intrinsic, local structure of actors within the e-waste management system. The data collection was limited in its ability to detect the true presence and scope of the informal participants within the network. As such, the above visualizations mainly reflect the roles of the official processors, corporations, government organizations and refurbishers. A further examination of the local system will likely paint a different portrayal of the links within the network as well as unveil a larger group of the informal processors. Nonetheless, the above network does provide a good illustration of the distribution of activities between several key organizations. This aspect of the collaborations is also reflected in another network characteristic: the material flow. The actual distribution of material also plays a strong role in determining the dominant actors within the network and creating important alliance.

Figure 6.2 Network alliances for key actors in Toronto e-waste management

a) Network alliances for the Recycling Qualification Office



b) Network alliances for the Ontario Electronic Stewardship

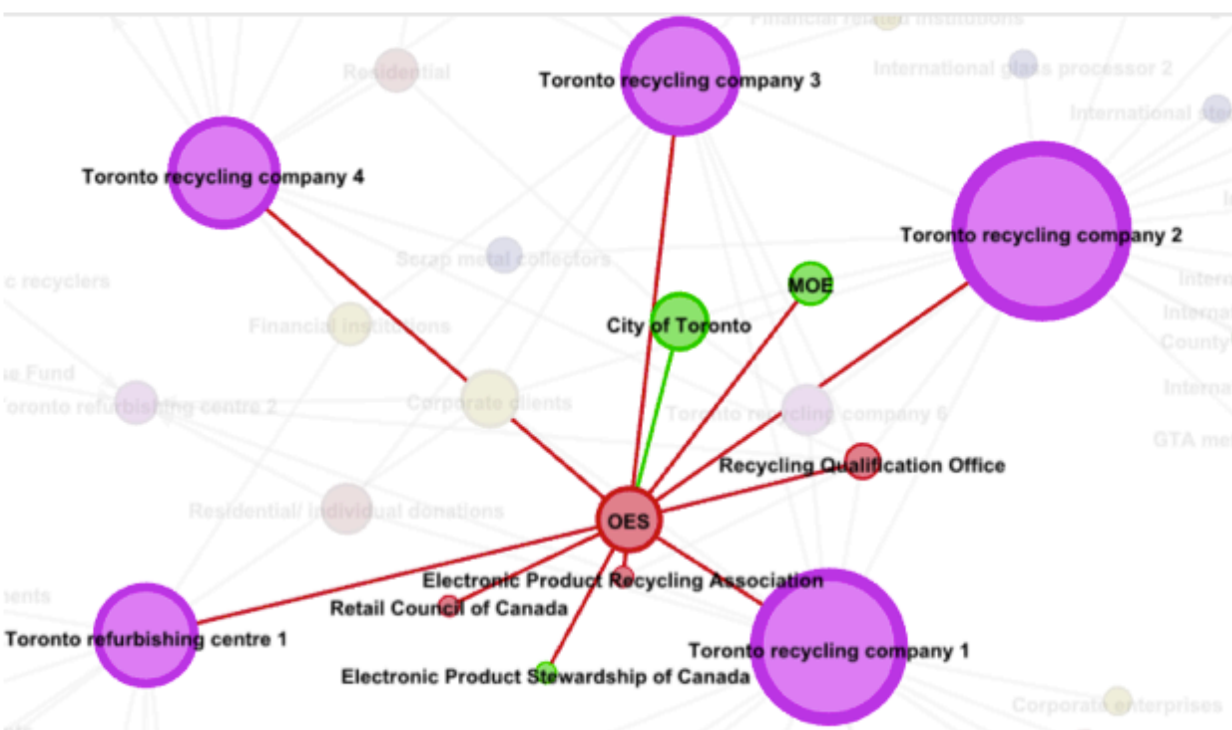
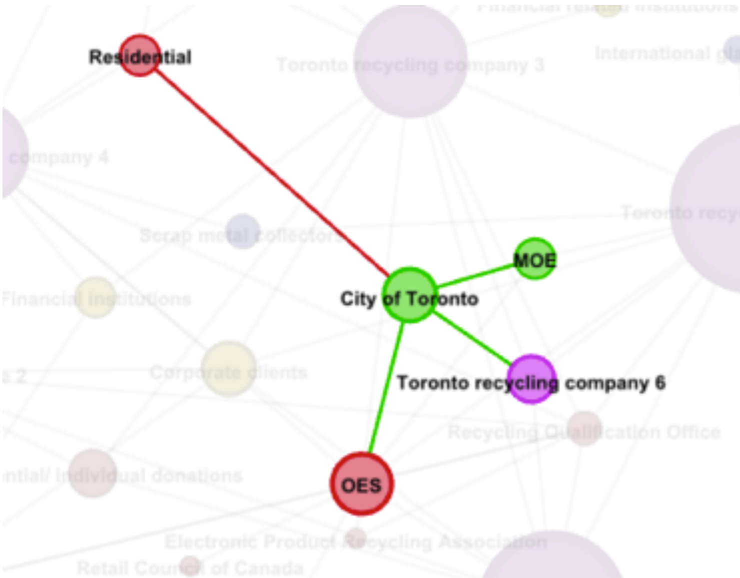
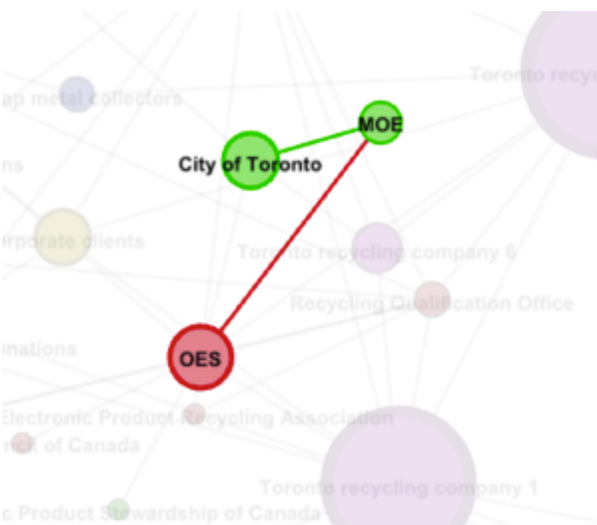


Figure 6.2 continued

c) Network alliances for the City of Toronto



d) Network alliances for the Ministry of the Environment



6.2.2. Material Flow Networks

The state of electronic waste management can be understood through the analysis of the social relationships as well as the actual movement/ flow of electronic waste between the actors in a network. The above examination of the social collaborations within the network has revealed some uneven distribution of each actor's involvement within the system. Their roles within the network can arguably affect their ability to acquire, and/or benefit from the collection of the necessary electronic waste. This relationship is visualized in the Material Flow Networks in Figure 6.2 and 6.3. The overall distribution of the electronic waste within the Toronto CMA area is summarized in the diagrams. While Figure 6.2 emphasises the different types of organizations involved in the network, Figure 6.3 categorises the types of material flow (inputs, outputs for recycling and outputs for refurbishing). The networks reveal a number of variations within the source, quantity and the final distribution of the electronic material.

Figure 6.3 The Material Flow Network for the electronic waste management system in Toronto Census Metropolitan Area. This network emphasises the different types of organizations (categorized by colour) that are involved in the material flow. The size of the edges (arrows) is scaled based on the total weight (in metric tonnes) of the e-waste involved in the transaction. The size of the nodes (actors) is scaled based on the total amount (in metric tonnes) of e-waste processed by each actor.

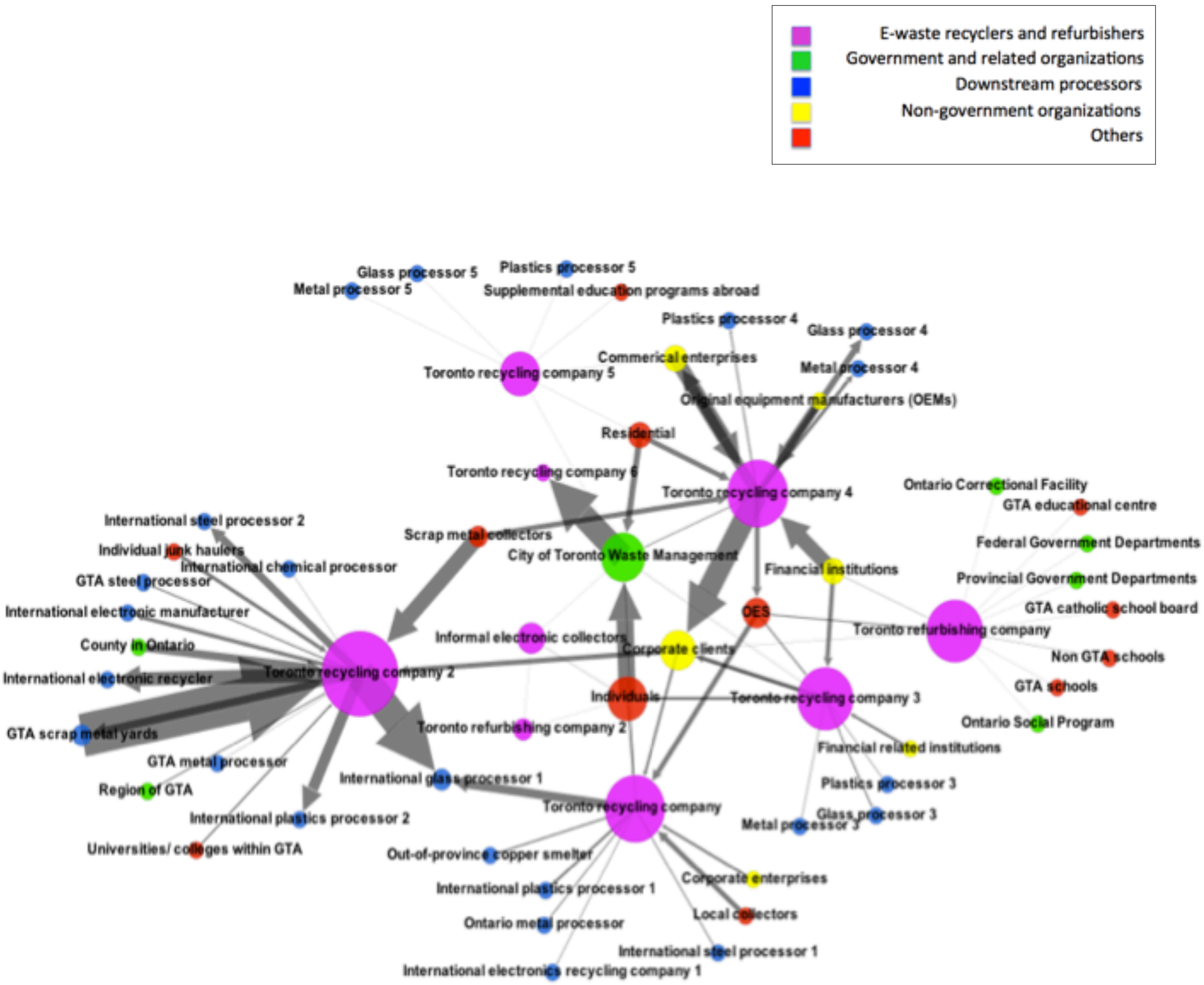
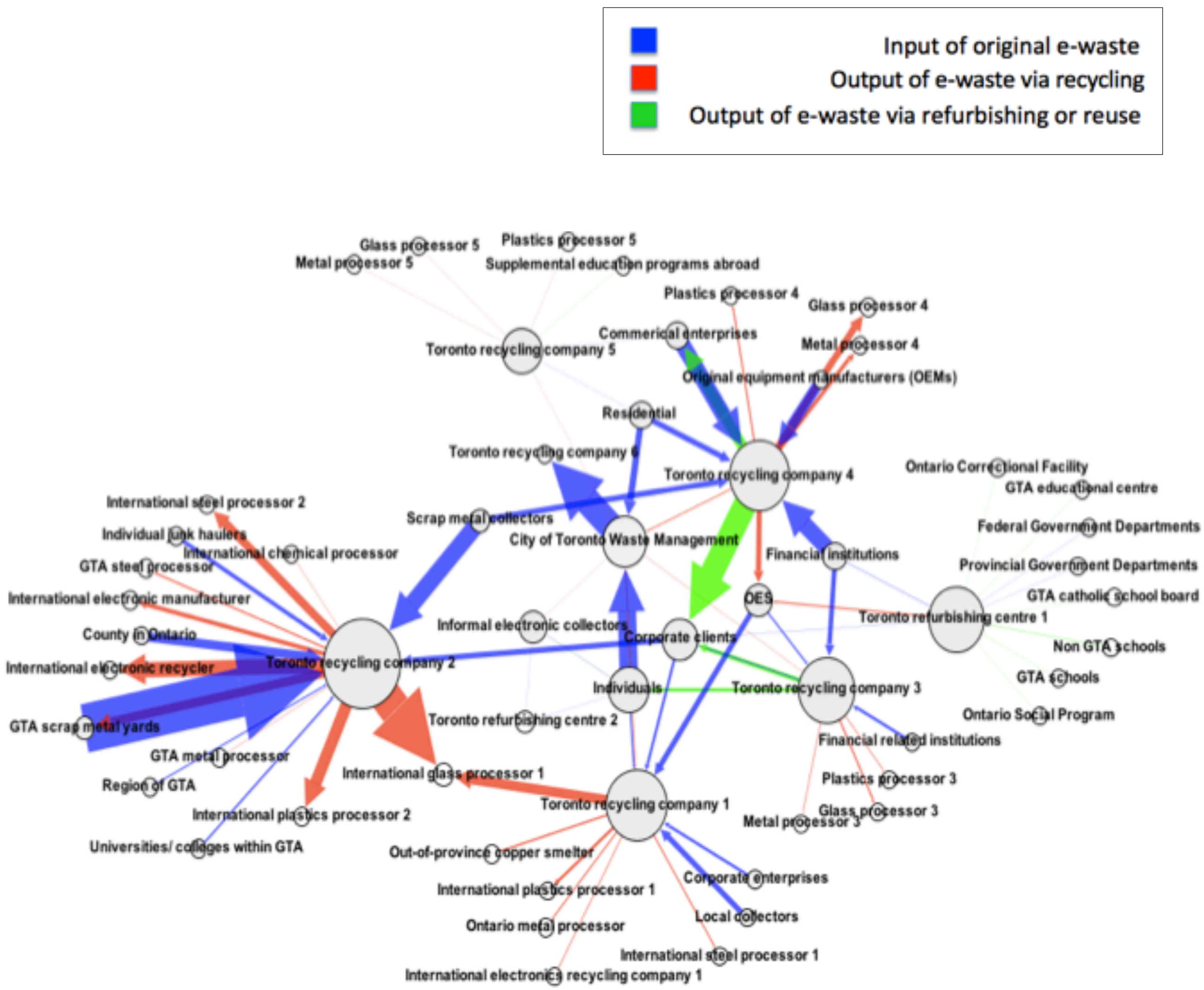


Figure 6.4 The Material Flow Network for the electronic waste management system in Toronto Census Metropolitan Area. This network emphasises the different types of transactions (categorized by colour) between the actors in the network. The size of the edges (arrows) is scaled based on the total weight (in metric tonnes) of the e-waste involved in the transaction. The size of the nodes (actors) is scaled based on the total amount (in metric tonnes) of e-waste processed by each actor.



The quantity of materials handled by each individual organization in Toronto fluctuates greatly within the fieldwork sample. The flow of the materials (visualized by arrows in Figure 6.3 and 6.4) is scaled based on the input and output reported by each organization during the interviews (the information supplied by the participants was reported in metric tonnes of e-waste). [18] The variation in the size of the arrows reflects the different scales of the average tonnage of electronic waste that has been accepted, processed, and sent 'downstream' by each company. The inputs and outputs range to such an extent that some material flow is barely visible in the Figures. For example, based on the primary visual observations, the amount of material processed by the Toronto refurbishing company 1 is overshadowed by the high inputs and outputs of the Toronto electronic recycling company 2. Similar observations can identify the actors that handle the majority of the electronic waste within the sample area. In Figure 6.3, the main sources and receptors of the e-waste are identified by their relatively large size of the nodes. Upon initial visual examination, the main receptors and sources of electronic waste include all of Toronto large-scale recycling companies (purple), City of Toronto waste management (green), Corporate clients (yellow), Commercial enterprises (yellow), Ontario Electronic Stewardship (red), and Financial Institutions (yellow). This type of visual analysis provides a certain insight into the general distribution of materials in the network. Yet, the extent of the disproportionality is harder to reveal without more relevant quantitative information.

[18] The measurement used for waste diversion reporting has yielded a number of debates in the past. In general, waste has always been reported in total weight of material (most commonly metric tonnes). However, our discussion in Chapter 2 suggests that the actual value of the material is determined by the content of precious minerals, not total weight. While a measure of valuable content would be a useful characteristic, accessing this kind of information was beyond the capability of the researcher. Most companies report their inputs and outputs in metric tonnes. As result, these were the only data available to the researcher.

Chapter 4 and 5 argue that the quantity of material processed by an electronic recycler or refurbisher impacts their long-term sustainability. The current e-waste management program impacts the participation of certain actors (e-waste processors) over the others (Section 4.2). While the previous Chapters alluded to the identification of the key actors (i.e. handlers of the majority of the e-waste), actual quantitative identification of the main processors can benefit the analysis further. The key distributors and processors of electronic waste material can be identified through data analysis. For example, Section 6.2.1. referred to the measurement of degree centrality. Weighted degree centrality is a very similar concept, yet, it also considers the 'weight' (in our case the reported input and output of electronic waste in tonnes) for each organization. This measurement reveals the main processors and contributors of electronic waste, by actual quantity of material. Top fifteen actors are displayed in Table 6.2 and Table 6.3.

The two Tables emphasize the organizations that receive and distribute the majority of the e-waste within the research area. Table 6.2 lists the fifteen top processors that receive the largest quantities of electronic waste from other organizations within the network. The processors are sorted in order of the total tonnage of incoming e-waste (weighted in-degree). Table 6.3 lists the top fifteeen processors that supply the largest quantities of 'raw' e-waste as well as already recycled or refurbished material to other organizations within the network. The top suppliers of e-waste are listed in the order of the highest quantity (in metric tonnes) of material (weighted out-degree).

Table 6.2 The top 15 organization within the Material Flow Network in electronic waste management in Toronto, sorted based on Weighted in-degree.

Label	ORGtype	Weighted In-Degree
Toronto recycling company 2	Recycler	6300
Toronto recycling company 4	Recycler	4127
International glass processor 1	Downstream	3220
Corporate clients	Corporation	2196
City of Toronto Waste Management	Government	2189
Toronto recycling company 6	Recycler	2000
Toronto recycling company	Recycler	1400
International electronic recycler	Downstream	1071
International plastics processor 2	Downstream	945
Toronto recycling company 3	Recycler	852
Commerical enterprises	Corporation	825
GTA scrap metal yards	Downstream	630
International steel processor 2	Downstream	630
Glass processor 4	Downstream	537
OES	Other	526

Table 6.3 The top 15 organization within the Material Flow Network in electronic waste management in Toronto, sorted based on Weighted out-degree.

Label	ORGtype	Weighted Out-Degree
Toronto recycling company 2	Recycler	6301
Toronto recycling company 4	Recycler	4128
GTA scrap metal yards	Downstream	3400
City of Toronto Waste Management	Government	2000
Scrap metal collectors	Other	1713
Individuals	Other	1684
Financial institutions	Corporation	1659
Toronto recycling company	Recycler	1400
Commerical enterprises	Corporation	1242
Residential	Other	935
Toronto recycling company 3	Recycler	852
Original equipment manufacturers (OEMs)	Corporation	825
Corporate clients	Corporation	715
County in Ontario	Government	640
OES	Other	548

The immediate observation of the weighted degree centrality in the two Tables points to the great range in the total tonnage of processed material between the top fifteen organizations. The total quantity of electronic waste that is handled by each of the organizations greatly varies. While the top processors of e-waste (recyclers) handle as much as 6000 tonnes of material, the smaller, specialized downstream processors (glass processor or metal smelters) handle approximately 600 tonnes of the material available within the network. It is likely that each organization's role acts as a determining factor for such allocation. The specialization of different downstream recyclers has a particularly strong effect on the final distribution of the material. For example, each recycler that breaks down their electronics into multiple components (glass, plastic, metal) will most often require a number of appropriate downstream processors to deal with each category.[19] As such, the outputs (red arrows in Figure 6.4) are mainly dictated by the steps that are required for the recycling and refurbishing of electronics.

On the other hand, the source of the initial input of the material (blue) is affected by the relationships between the actors (Figure 6.4). While some processors gain large quantities of e-waste from private corporations and institutions, others struggle to compete for material. As a result, the suppliers of high-quantity of material have a stronger influence on the network. Based on the numerical data in Table 6.3, the largest inputs of e-waste appear to be originating from several electronic waste Processors, GTA scrap metal yards, City of Toronto Waste Management, Financial Institutions, Commercial and corporate enterprises, Individuals (i.e. Residents) and Scrap metal collectors. The material sourced from the private recycling companies (Toronto Recycling company 2 and 4) is likely represented by mostly recycled electronic waste components that are sent downstream to individual processors (smelters, plastic manufacturers etc.). These transactions are discussed in more detail in Chapter 4. However, they do not necessarily account for the source of the 'raw' (unprocessed electronic waste that has been directly collected from primary sources) material. On the other hand, the other top sources of e-waste (GTA scrap metal yards, City

[19] There are a few material categories (such as plastic) that can undergo all stages of processing (from initial shredding to preparation for further production) at a single e-waste processing site. The capacity of each organization to fully process each type of material varies with individual organization. It mostly depends on the technology that is available to each processor.

of Toronto Waste Management, Financial Institutions, Commercial and corporate enterprises, Individuals (i.e. Residents) and Scrap metal collectors) are likely able to supply the primary collected electronic waste. These actors can be thus identified as the dominant sources of electronic waste within the sample fieldwork area. As a result, the quantity and quality of electronics that each of them supply directly dictate the fate of the material within the network. The following section will address each one of the actors individually.

The City of Toronto's approximate diversion of 2000 tonnes/ annually (please refer to Table 6.3 and Chapter 5) through its extensive electronic waste management program is reflected on the map. It is important to point out however, that all of the City's current electronic waste is supplied to a single electronic processor (Figure 6.3). The City is also supplied with the leftover 'scraps' from some electronic waste processors that are designated for landfill. By controlling this quantity of e-waste, the City thus dictates its future allocation (Chapter 5). While the municipal government does appear to hold a strong role within the network, the same cannot be applied to the provincial government. Ontario Electronic Stewardships does not appear to have a high impact on the input and output of materials in the visual network. This characteristic can be attributed to the nature of the 'bounty program', described in Chapter 4. While OES does directly handle a portion of the collected electronics while storing them in their consolidation centres, most of the interviewed processors do not receive materials directly from the centres but acquire it from the clients directly. These transactions are still a part of the registered OES process. Yet, for the purpose of our Material Flow Network, they occur solely between the client and the processor.

Other categories of important contributors include the Financial institutions and Corporate and Commercial enterprises. In fact, it is these organizations that are able to supply very large quantities of materials at once (Chapter 5; Interviewee # 7, May 31, 2013; Interviewee #23, August 22, 2013). In total, several different corporations were reported to contribute over 4400 tonnes[20] to the electronic waste market (Table 6.2). A number of large corporations have a policy that requires a regular upgrade of their electronics. These companies usually deal with only one electronic waste processor who is supplied with all of their IT electronics (Interviewee # 7, May 31, 2013). This policy enables banks and large private corporations to supply individual e-waste processors with a significant quantity of good quality electronics. As a result, these processors most often specialize in electronic refurbishing, rather then recycling. There are not too many companies of this type in the current market. In fact, the researcher was only able to secure an interview with one company who deals with large-scale refurbishing (Toronto recycling company 4 in Figure 6.3). As it is apparent in Table 6.3, this company's specialization does seem to be beneficial to its wellbeing. The company individually processes over 4000 tonnes of e-waste. Additionally, this type of a relationship is beneficial to the supplier as well as the processor. The Financial institutions and other corporations profit from the sale of their discarded material. This type of a symbiotic relationship yet again demonstrates the role that alliances play in the e-waste management network. These relationships between large scale actors within the network can strongly affect the long-term sustainability of electronic waste management in Toronto. If this type of a relationship proves to be beneficial to a number of

[20] Total sum of 1659, 1242, 825 and 715 tonnes of material supplied by various Corporations

large-scale suppliers of raw e-waste (banks, school boards etc.), the presence of large-scale refurbishing could grow in the overall network. Based on the observations by Kahhat et al. (2008) and Williams et al. (2008), refurbishing and reuse of electronics can mitigate the high energy costs of production of electronics. Thus, such large-scale reuse can benefit the economic and environmental factors of e-waste management. On the other hand, if only a few e-waste processors become interested in this type of refurbishing, these types of alliances can disappear all together from the e-waste management network.

The scrap metal yards and scrap metal collectors also play a significant role in electronic waste management. This particular group's presence was not previously evident in our review of the market in Chapters 4 and 5. In combination, these organizations have been reported to contribute over 5000 tonnes of electronics to a number of different processors (Table 6.3). As previously mentioned, most of the interviewees were unwilling to discuss the actual names of the organizations that they deal with. As a result, the researcher can only hypothesize the role that these actors play in electronic waste management. It can be assumed that these organizations are either supplied with electronics through their clients or find discarded material in various parts of the City. Nonetheless, these companies' ability to contribute such a large quantity of questionably sourced material is relatively alarming from the environmental and economic sustainability perspective. It is likely that the participation of these types of organizations is more apparent from the local (vernacular) (Scott, 2012) perspective of the waste management system. As such, further examination of the 'non-official' order of actors could supply the necessary complimentary information on the real quantity of electronics processed in Toronto. As mentioned in Chapter 2, it is possible that a large quantity of electronic waste is not currently being accounted for

(Section 2.3). Proper identification of the actual amount of available e-waste will likely play a determining role in the future management strategies. Yet, the above example supports the notion that the reported amounts of electronic waste for the City of Toronto, as well as the province, likely do not reflect the actual quantity of available material.

Another important characteristic that is apparent in the Material Flow Network in Figure 6.4 is the final destiny of the outputted material (i.e. whether it has been refurbished, reused or recycled). The flow of electronic waste is classified into inputs (blue), outputs through recycling (red) and outputs through refurbishing (green). The distribution of the recycled vs. refurbished electronic material provides an interesting, yet expected, storyline. As it is apparent in Figure 6.4, the majority of outputs are displayed in red with only a few visible arrows shown in green. The two Toronto refurbishing companies do provide some contribution to the overall network. However, with respect to total tonnage, the amount of electronics that they are able to process is not significant enough to be clearly visible on the map. In fact, the total output for one of the refurbishers does not exceed 200 tonnes. At the same time, some of the recyclers are able to process upwards of 6000 tonnes/ year (Table 6.3). In reality, the only 'significant' output of refurbished material is provided by the Toronto recycling company 4 (Section 6.3). This allocation of materials for recycling vs. refurbishing adds to the already developed storyline of relative inequality within the network. It will be one of the issues that will be discussed in more detail from the perspective of the sustainability in the following sections.

To summarize, the Material Flow Networks support the already developed narrative of great variability within the flow of material and development of alliances in the electronic waste management network in Toronto. Similar to the relationships within the

Collaboration Network, the material flow is unevenly distributed between the processors within the network. The distribution of material appears to be dictated by a number of large-scale recyclers, government agencies, financial and corporate organizations. At the same time, the refurbishing organizations appear to be processing a significantly smaller portion of materials than the rest of the network. Consequently, the refurbishing efforts within the whole network are overshadowed by recycling. These conclusions are similar to those drawn from the initial examination of the management system in Chapters 4 and 5. The significance of such network characteristics will be discussed in the following sections.

Overall, the above networks add to the understanding of the structure of electronic waste management in Toronto. They complement the description of the electronic waste management system in Toronto present in Chapters 4 and 5. The data analysis of the networks provides further insight into the actor's ability to participate and influence the decisions making process within the current waste management system. According to the results of the "Collaboration Network", some of the actors within the network hold more influential positions than other. In fact, the influence on the management of electronic waste appears to be dominated by the representatives from the industry and government. Similarly, the quantitative allocation of material within the network suggests a certain level of inequality as well. Perhaps the key contribution from the material and social network analysis is the outline of the proportion of the network that is dedicated to the reuse and refurbishing or electronics, rather than recycling. The network diagrams show the number of organizations committed to electronic refurbishing (Figure 6.1) and the quantity of materials (Figure 6.4) that is being refurbished. Brief visual analysis of the images suggest that (a) the small number (2) of refurbishing organizations are not as closely incorporated into the social network of electronic waste management in Toronto (Figure 6.1) (b) the quantity of electronic waste that is being refurbished is significantly smaller than the quantity designated for recycling (Figure 6.4). This visual interpretation of the current state of electronic waste management quickly points to the shortcoming of the established system. As mentioned earlier, the key to a sustainable waste management strategy is the hierarchy of the three R’s (reduce, reuse, recycle). As long as recycling overshadows the reuse and refurbishing efforts, the sustainability of the electronic waste management system in Toronto is questionable.

All of the above characteristics point to a number of potential issues within the actual state of electronic waste management in the Toronto CMA. Yet, in order to truly address the second research question: How, if at all, can the sustainability of the existing system be enhanced? we must proceed to analyzing the findings from the fieldwork within the context of sustainability as it has been developed in the literature review. The following sections will provide this analysis.

6.3 Sustainability analysis of existent electronic waste management system

The above descriptions of the current electronic waste management system in Toronto have pointed out a number of specific characteristics that have an affect on the current and future sustainability of the program. In order to ascertain the capacity of the current electronic waste networks to address the pillars of sustainability, several characteristics will be addressed in this section. The attributes of the management system that will be covered in more detail will include: (1) the scale of the management program; (2) the allocation of material between different companies and individuals; (3) the distribution of relationships within the network; (4) the prioritization between material recycling and refurbishing and its effect on social sustainability. The uneven access for participation within the market must have an effect on the small-scale electronic recyclers and refurbishes, some of which are already struggling to make ends meet. The material allocation can play an indirect role in the maintenance of safety and environmental standards. The distribution of electronics destined for recycling vs. refurbishing can limit the level of social and environmental sustainability within the network. Yet, perhaps one of the most significant issues is the scale of the program and its boundaries.

The sustainability of any urban waste management program is affected by the geographical restriction of the movement of waste. Insuring a more local scale of waste management can help achieve some of the characteristics associated with the ideal 'urban metabolism' discussed in Chapter 2 (Kennedy et al, 2007; Girardet, 2008). Yet, as it has been previously mentioned, many of the clients and downstream processors within our network are located outside of the geographical area of research project. In fact, some of the actors within the Material Flow Network are located outside of the country's boundaries. As it is visible in Figure 6.3, a number of downstream processors were identified to be located outside of Canada or North America by their suppliers (the local e-waste recyclers and refurbishers). They are thus indicated as 'international' organizations on the network visualizations (Figures 6.1, 6.3 and 6.4). The broad distribution of the actors within the network can be explained by a number of reasons including: multiple office locations for some of the large corporate clients, greater competition of clients within the core urban area, and significantly smaller cost of downstream recycling associated with processors located outside of the province or country (Interviewee #7, May 31, 2013). Such broad geographic scope makes estimation of the total amount of material, which is being processed within the program, very difficult. “The challenge is to put fences around the system… Out of province leakage is a big issue” (Interviewee #26, October 11, 2013). The free flow of electronics outside of the urban and even provincial area creates a number of environmental and economic externalities. Most importantly, the flow of urban waste outside of the city’s jurisdiction does not agree with the ideal image of an urban ‘metabolism’ that has been established as a basis for the sustainable waste management system in Chapter 2 (Kennedy et al, 2007; Girardet, 2008).

The main problem associated with the ‘leakage’ is the ability to maintain a management program for all of the electronics. As with any other management program, there is a high cost associated with the provincial and municipal top-down management of the material. It is evident that the major costs are comprised of the supervision of the collection and sustainable disposal of the material (Interviewee #26, October 11, 2013; OES, 2013). From the provincial perspective, the program is mainly maintained by the inflow of the fees from the ‘stewards’, collected during the initial purchase of the electronics. In actuality, the bulk of the cost of the program has been passed on to the consumers and not the stewards (Lepawsky, 2012).[21] Regardless, the fees can only be collected from the transactions that occur within the geographic area of the province (Interviewee #26, October 11, 2013). At

[21] The fee calculation and collection methodology has served as a source for debates in popular media and academia. However, the in-depth discussion pertaining to the legal geographies associated with the Canadian e-waste management is beyond the scope of this project. For more information please refer to Lepawsky (2012).

the same time, it is likely that for a City the size of Toronto, a large portion of its electronic waste could have been originally purchased outside of the province. As such, the provincial management program does not receive the necessary fees but is still responsible for supervising the disposal of the items.

At the end of the day, such distribution of the electronics during their life and at the time of the 'death' can have a detrimental effect on the long-term economic sustainability of the program. Similarly, the broader scale distribution of electronic waste to areas outside of the city may result in environmental problems. According to the literature, sustainable urban metabolism must be able to absorb the negative environmental effects of waste production and disposal within the geographic area of the city and its surroundings (Kennedy et al, 2007). Our conclusions from Chapter 2 suggest that electronic waste must be processed with caution in order to mitigate the harmful environmental and health effects of the toxic materials. The environmental sustainability of electronic recycling and refurbishing appears to be on the forefront of most actors within the network. Yet, fieldwork research has demonstrated that the standards are not evenly applied within all organizations inside and outside of the network.

First of all, it is important to point out that the environmental standards that are enforced and practiced by actors involved in e-waste management are varied. Some of the recycling companies do pride themselves in sending their materials to only 'local' downstream processors. Yet, the actual locality of the processors is a debatable subject. In a country the size of Canada, a 'local' smelter to a Toronto company can be located in Northern Ontario or Southern Manitoba, approximately 1000 kilometers away (Interviewee #17, August 8, 2013). The environmental effect of shipping 100s of tones of electronic waste over such a distance is likely significant. According to the calculations performed by Barba-Gutierrez and colleagues (2008), for example, the most optimal shipping distance for WEEE recycling, in terms of environmental effects, ranges between 200 and 300 km. At the same time, as it is visible in Figure 6.3, a large number of downstream processors are located outside of the country, significantly further than 300 km. To add to the negative externalities of transportation, the processing standards for the downstream recyclers are varied on a provincial and international level. At this point, it is nearly impossible to calculate the complete externalities of shipping and processing of electronic waste far away. It is likely that international trade of electronic waste could have positive social benefits to local communities, as demonstrated in several examples in the Literature Review section (Streicher-Porte et al, 2009). However, from the environmental perspective, trade of e-waste over long distances has adverse effects on the local urban sustainability of e-waste management.

In addition to the discrepancies in practiced environmental standards within each organization, the health standards are also subject to variability. The preventative technologies and practices in place at the recycling and refurbishing facilities are surprisingly not standardized throughout all the locations. While the basic protection such as masks, goggles and gloves is evenly supplied to each recycler, the standardization seems to end there. While some of the facilities are going beyond the required safety standards with installed air purification filters, safety stations and complex equipment etc., others simply consist of rows of tables and boxes of various tools (Personal observation during multiple site visits, June to August, 2013). Even though the majority of activities involved in e-waste disassembly do not require excessive safety equipment (respirators, face masks etc.), basic precautions are still necessary. Alarmingly, several members of the refurbishing facilities opted to not wear any safety equipment (gloves, goggles) while dismantling the electronics. The sharp chunks of thin aluminum and copper were often pried off with a dull screwdriver or bare hands (a practice that left the researcher with a cut finger at one point). These inconsistencies in safety practices within the registered OES processors, have led the researcher to question the impact that electronic waste management is having on social sustainability and safety within the network. The broader scale of the management program undermines the application of consistent environmental and health and safety standards. As a result, the environmental, economic and social sustainability of the system are being affected. Yet, there are other factors that also add to the uncovered problem of the scale of the network. A number of other system characteristics directly limit the social sustainability of the electronic waste management program.

Accessibility to electronic waste affects the organizations themselves but also creates an uneven distribution of material between the organizations' clients. As mentioned in Chapter 4, the few refurbishing companies in Toronto are a part of a different niche of electronic management. It is these companies that often provide the less affluent portion of the population with not only the access to affordable technology but also ability to gain some technological knowledge. Yet, according to the Collaboration and the Material Flow Networks (Figure 6.1 and 6.3) these organizations often find themselves on the periphery of the existent network. Their participation in the decision-making within the network is limited by their alliances with 'influential' actors. In addition, the total amount of material they process is almost negligible in comparison to some of the large-scale recyclers in the city.

Such allocation of material likely affects the organizations as well as their clients and members. A further examination of the characteristics of the members/ volunteers of one of the refurbishing centers points to a number of potential impacts of such material distribution.

Access to computer technology plays a role in social sustainability in the current information technology age (Anderson et al, 1995). We have already discussed how the high costs are limiting the distribution of electronics to some parts of the population. It has also been highlighted that electronic refurbishing may serve as a solution to this problem. Refurbished electronics are commonly sold at lower prices that are more accessible to poorer residents (Interviewee #16, July 9, 2013). It is also apparent from our Material Flow illustration that the majority of reported electronic waste is not supplied to the refurbishing organizations (Figures 6.3 and 6.4). This suggests that the current electronic waste management network does not support social sustainability to its fullest potential. At the same time, despite the above circumstances, it is likely that a significant portion of the electronics that are collected by the informal market are being refurbished. Several members of one of the refurbishing companies admitted to regularly participating in electronic waste scavenging. In fact, some of them have reported fixing the found electronics at the actual refurbishing centre.

> "There is one computer I found. 17 inch, plasma but it's ACER. Nobody likes ACER. But I do! Throw them all out! I'll take them! Somebody needs a computer and I have one. I can fix it and I'm not using it. I just say "Here", it cost me nothing…" - (Interviewee #10, June 10, 2013)

The members of the refurbishing centre also fix clients' computers at the centre. This type of service is unlikely to be in demand within the population to whom the cost of electronics is less significant. "Often enough, people just throw out the electronics as soon as they break" (Interviewee #10, June 10, 2013). Yet, the repair service is useful for many residents.

> "A lot of the people that come here with problems are not very well off either. Some of the electronics they bring are really easy to fix… Also, sometimes it takes longer because I made a mistake. It's not fair to charge someone for my mistakes. So I just subtract that time. If it's really easy to fix, I just do it for free" - Interviewee #14, June 12, 2013

It is likely that such acts of kindness do contribute to the distribution of the electronics within the market. Nonetheless, the total quantity of the electronics that are being supplied and processed in such a manner is unclear. Based on the currently obscure presence of the informal recyclers within the system, it will be somewhat challenging to measure their exact material input in the immediate future. At the same time, the quantity of refurbished electronics by the large companies is measurable (Please see Figure 6.3). At the moment it remains significantly lower than the quantity that is being recycled. Unless the electronic waste management program changes its direction anytime soon, it is likely that the quantity of refurbished electronic will continue diminishing. The above-portrayed domination of the market by the large-scale recycling corporations speaks to this topic.

It should also be mentioned that the uneven distribution of electronic waste has an effect on the job market. As highlighted in Chapter 2, manual disassembly of electronics and electronic refurbishing is able to supply a greater quantity of jobs in comparison to mechanical recycling. Large-scale recycling of electronics generally involves a more mechanised series of procedures involving shredders, centrifugal separation and multiple material separation lines. These facilities mainly hire a few technicians and some lesser skilled workers for the manual 'control' checks of the material disassembly lines. On the other hand, re-use and refurbishing of electronics involves hours of specifically skilled manual labour. People skilled at electronic refurbishing and re-use require a thorough knowledge of the technology behind electronic assembly.

The data collected through the fieldwork also supports the above characteristics of the reuse sector. During the site visits, the large-scale recycling facilities displayed much higher numbers of employees than the refurbishing centre. However, it is not the quantity but the quality of jobs that holds the most importance in this discussion. Computer refurbishing has much greater potential to contribute an array of highly specialized work opportunities to the field of electronic waste management. This hypothesis was supported by the field observations. While the two refurbishing centers did not host a large number of staff and volunteer, the types of jobs available at the centers were much more specialized than at the recycling centers. The refurbishing organizations were able to supply their employees with access to new sets of technical skills, including computer refurbishing, software installation and hardware installation (Interviewee #16, July 9, 2013). The volunteers and staff at the centers were largely responsible for disassembling and testing the computers, fixing the software or hardware, installing software or hardware and compiling orders for clients. On the other hand, the majority of the employees at the recycling facilities performed simple sorting or disassembly duties. It is likely that the more specialized technical skills gained through electronic refurbishing will benefit the volunteers and staff in their careers and future work opportunities. In fact, many of the interviewed volunteers named ‘learning’, ‘access to technical skills’, ‘gaining work experience’ as the primary reasons for their commitment to the centers. Keeping in line with that storyline, one can only begin to question the effect of the relatively small presence of such opportunities. Currently, the two non-profit refurbishing companies include no more than fifty or sixty staff and volunteers. That number is dwarfed by the scale of the electronic waste management system in Toronto. While these types of jobs are sought after and needed for the development of technical skills by the local residents, it is unlikely that given the current structure of the market, electronic refurbishing will be able to flourish in the near future.

In conclusion, the sustainability of electronic waste management in the city seems to be affected by a number of factors. Firstly, the vague scale of the boundaries of the provincial management systems results in economic and environmental externalities. Secondly, the higher distribution of material to recycling organizations than refurbishing efforts directly affects the smaller refurbishing companies as well as their clients. Lastly, the lack of accessibility to refurbishing limits an opportunity for the provision of specialized technical jobs in the urban area. Overall, the current distribution of material and relationships within the two examined networks may undermine the future sustainability of the electronic waste management in Toronto.

6.4 Conclusion

This Chapter was intended to provide a holistic picture of the electronic waste management system in Toronto. The social alliances and flow of material between the actors were analyzed through the visual and statistical assessment of the networks. The networks were then analyzed for the presence of the characteristics of an ideal image of a sustainable e-waste management system (Chapter 2). The state of the current and future environmental, economic and social sustainability was discussed to identify a number of barriers to the development of a sustainable electronic waste management system. The primary concern was associated with the absence of geographic boundaries for the movement of the material. Particularly, it appeared that a large quantity of electronic waste is undergoing final processing outside of the urban and provincial areas. This flow of e-waste can have negative environmental and economic effects. Additionally, the lack of boundaries makes it very difficult to effectively assess the sustainability of the whole system. The broad geographic scale also complicates the enforcement of consistent environmental, health and safety standards within the recycling and refurbishing sectors. The variation within the workplace safety standards was of particular concern to the researcher. In addition, several other factors, such as the uneven distribution of e-waste and refurbished electronics, were also undermining the level of social sustainability within the system. The lower volume of material allocation to the refurbishing efforts was tied to the limited accessibility of second-hand electronics to the City's residents. Consequently, the scale of electronic refurbishing within the network limited the creation of skilled technical jobs. In conclusion, a number of problematic characteristics have been identified as barriers to the successful modification of a sustainable waste management network in the Toronto Census Metropolitan Area.

Chapter 7: Conclusion and recommendations

7.1 Sustainability of e-waste management in Toronto

Waste management, including electronic waste management, is a key aspect of sustainable urban development. The creation of sustainable electronic waste management program is necessary for the diversion of the vast amounts of electronic material that are produced worldwide. However, more research on the feasible implementation of sustainability ideals in electronic waste management is required. The promotion of sustainable electronic waste management strategies can be enhanced through the exploration of existing management systems. Consequently, recent literature focuses on the analysis of the roles of various sectors within the current waste management programs. A significant body of research explores a single category of the waste management sectors (large-scale mechanical; small-scale entrepreneurs; manual and informal processors etc.) separately (Gregson et al, 2012; Gutberlet, 2012; Wilson et al, 2006 among others). While many conclusions have been drawn on the essential components of each individual actor, more analysis of the interrelationships between multiple sectors is needed. Additionally, the dialogue that has been predominantly focused on the developing areas worldwide must be inclusive of developed urban areas, like Toronto, as well.

The discourse of sustainability can be usefully applied to the analysis of electronic waste management in an urban centre. As per the discussion developed in Chapter 2, sustainability can be expressed through its three pillars (environmental, economic and social). Strong cohesion must be developed between the environmental, economic and social goals. An inability to create constructive discourse between the goals of each pillar can result in unnecessary conflict of priorities (Gibson, 2005). Thus, if the pillars approach is used as a basis for analysis, an ideal sustainable electronic waste management system must incorporate each pillar equally.

Arguably, just as the sustainability discourse cannot be addressed through the analysis of a single pillar, the sustainability of the waste management system can hardly be determined based on the contributions of only a few actors. As a result, this project focused on the sustainability analysis of the complex interrelationships between multiple actors within the current electronic waste management system in Toronto. The Network Analysis Methodology played a key role in highlighting the current structure of the relationships within the network. Each actors' effects on the three pillars of sustainability were analyzed.

The conclusions from the fieldwork data collection and analysis highlight a number of positive and negative effects that each actor has on the sustainability of the electronic waste system. Overall, it is impossible to identify a single actor that should play a dominant role within the current and future management system. This conclusion supports the literature's focus of the importance of multi-sector alliances to promote the development of a sustainable management system (Scheinberg, 2011; Wilson et al, 2006; Hageluken, 2006; Baud et al. 2001). Each sector, analyzed within the fieldwork, plays an important role within the current system. The government organizations; large-scale processors; non-profit refurbishes, and the informal processors all have the capacity to address certain aspects of the 'ideal' image of sustainability. However, each one of them has a different ability to become further involved within the network as well as assert influence on the structure of the management program. The following sections highlight each actors' impact on the current and future sustainability of electronic waste management in Toronto. The discussion is separated into three sections; each addressing an individual pillar of sustainability. Conclusions on the overall state of the network of e-waste management are drawn. Recommendations for further research, policy and planning implementation are provided.

7.2 The limitations of the pillars approach

Although the pillars approach has been chosen as a basis for the analysis within this thesis, it has a number of limitations. The importance of the necessary interrelationships between the goals of the three pillars cannot be stressed enough. Unfortunately, a number of management approaches in the past have been unable to harness the positive commonalities between the social, environmental and economic goals and have instead focused on the conflict of interests (Gibson, 2005). This type of negative reinforcement can be destructive to the creation of sustainable policies and communities. To prevent such conflicts, some have suggested an alternative assessment methodology to the three pillars.

In his book on sustainability assessment, Robert Gibson (2005) highlights the importance of 'supplementary criteria' to help address the trade-offs that often arise between the environmental, social and economic goals. In a world of 'connections and interdependencies' it is often difficult to draw barriers between different categories of concerns (Gibson, 2005). As a result, an assessment methodology that is more focused on interconnections and interdependencies is necessary. Gibson thus proposes a list of eight criteria by which the core necessary elements of sustainability can be measured. Each one of the core criteria incorporates ecological, social and economic elements into its goals. If embraced, this approach could create a different portrayal of the management systems. An e-waste sustainability assessment using the above methodology will likely reveal a different illustration of the existing system in Toronto. Most importantly, this type of an assessment methodology is better suited to unveil the more complex political context of e-waste management (a perspective that was mainly left untouched by the researcher throughout the project) (Gibson, 2005).

The different approach to sustainability assessment could provide an interesting parallel to the analysis completed as a part of this project. Exploration of several, or all, of the sustainability 'criteria' within an urban centre similar to Toronto could be the focus of future research on waste and e-waste management. In particular, a more in-depth political system assessment could be necessary to unveil the realities of such management programs. At the same time, the pillars approach can still be useful for a broad analysis of the current management practices. The interconnection between the goals of the three pillars, however, must be prioritized at all times.

7.3 Environmental sustainability of e-waste management in Toronto

The analysis of the e-waste management system in Toronto has revealed several successful aspects of the program as well as a number of shortcomings. The City of Toronto is relatively successful in diverting e-waste from the landfills. Yet, their efforts are strongly concentrated on the recycling part of the 3 R's (reduce, reuse, recycle). At the same time, the re-use/ refurbishing efforts are often undermined and waste prevention goals are absent from the official program. This section will highlight some of the key aspects of the existing e-waste management system.

According to the literature review in Chapter 2, the following characteristics of electronic waste management are particularly crucial to an environmentally sustainable management program.

- The total quantity of electronic waste produced in an urban centre must be managed within the geographic area of the city itself and/or its surrounding areas
- The environmental effects of e-waste management must be mitigated
- The need for newly extracted resources to sustain electronic production must be alleviated

Currently, each of the actors within the e-waste management network in Toronto contributes differently to the achievement of the above goals. The combined efforts from the different sectors of e-waste management are best suited to support the necessary components of current and future sustainable e-waste management.

From the perspective of a total e-waste processing capacity, the large-scale recycling sector has a strong dominance. Currently, the private electronic waste recyclers process the largest quantity of e-waste in Toronto. The individual companies, included in the fieldwork, demonstrate the ability to process from 10 to 6000 metric tonnes of electronics per annum (Section 4.2.2). The processing capacity of this sector enables it to majorly contribute to the sustainable management of e-waste within the urban area. For example, a single processor, located within the GTA, recycles all of the residential electronic waste, collected by the City of Toronto (approximately 2000 tonnes in 2012) (Interviewee #20, August 12, 2013).

This characteristic partially addresses the strive to maintain the 'metabolism' of a city within its current area and the area of its surroundings (Kennedy el al, 2007). Localized waste management can prevent the spread of negative environmental externalities outside of the urban boundaries. The large-scale recycling sector's ability to process such quantities of electronic waste makes it essential to the overall sustainability of the urban e-waste management system. Based on the findings from the study, no other sector in Toronto is currently capable of competing with the sheer volume of electronics processed by the recycling companies. However, the largely mechanized recycling process does have some negative characteristics.

The mechanized e-waste recycling process is limited in its ability to retrieve the precious materials from the old electronics (Hageluken, 2006). Manual disassembly, refurbishing and reuse are better suited to preserving the precious mineral components of e-waste (Manhart, 2011). Reusing electronics and valuable components like gold, silver and platinum, can decrease the necessity for the continuous material extraction and its associated environmental effects. Additionally, reuse and refurbishing of electronics can prolong their lifespan, and thus mitigate the energy required for the production of new devices (Williams et al, 2008; Kahhat et al, 2008). The material flow investigation (Chapter 4) showed that large-scale processors in Toronto concentrate their efforts on recycling and not reuse and refurbishing of electronics. On the other hand, the non-profit electronic refurbishers are able to redistribute a significant quantity of electronics into the market (Chapter 4). According to the fieldwork findings, a large portion of the material supplied by the two non-profits are distributed to local schools and the residential sector, thus remaining within the local area (Section 4.2.4). In addition, Toronto non-for profits' commitment to manual disassembly of electronics allows for a greater recovery of valuable parts and materials. This specialization in reuse and refurbishing additionally contributes to the environmental sustainability of local e-waste management.

Nonetheless, the large-scale recycling organizations also partially support the refurbishing sector's existence. Further evaluation of the network relationships (through SNA methodology) unveiled key partnerships between large-scale recycling organizations and the non-profit sector. Both of the non-profit refurbishers in Toronto rely on OES registered organizations to collect their extra, unused e-waste for recycling. This symbiotic relationship demonstrates the importance of the alliances between different e-waste management sectors. Arguably, a more even development of each sector of e-waste management will further promote the creation of such relationships. These alliances can in-turn ensure the development of a resilient, sustainable e-waste management.

A similar relationship appears to be forming between the City of Toronto and the informal sector. The informal recyclers and refurbishers rely on the City of Toronto's curbside collection program to in-directly provide them with old electronics. As previously mentioned, the current e-waste collection system in Toronto, does not actively facilitate the reuse or refurbishing of electronics locally (Chapter 5). Moreover, the e-waste items collected by the City omit a large portion of devices that are not currently accepted by the OES registered processors (Sections 4.2.3 and 5.2). The informal collection, which was recorded during fieldwork, seems to be partially addressing the above shortcomings of the City's official program. As it was unveiled during the researcher's interaction with a few self-identified 'scavengers', a significant quantity of curbside e-waste is reused and redistributed to the local residents (Chapter 5). Such pattern of local e-waste refurbishing and allocation agrees with the environmental sustainability's goals of e-waste management. The local redistribution of refurbished electronics also positively benefits social sustainability, which will be discussed later in the Chapter. Through their regular presence in the e-waste management system, the informal refurbishers and recyclers are adding a necessary level of disorder to the City's management program (Chapter 5). As previously mentioned, a perfectly ordered management system is unlikely to be successful in the long-term (Scott, 2012). The more informal activities, carried out by the scavengers in the City, are thus complimenting the official system by re-using and indirectly reducing e-waste (activities that the official program is not performing). However, the quantity of e-waste that is currently processed by the informal sector is difficult to estimate. Additionally, the final fate of the informally processed e-waste can only be hypothesized. These factors can have potentially negative consequences on the sustainability of the system.

According to Kennedy et al (2007) a sustainable urban centre should strive to limit its outputs (waste) to its geographical boundaries and surrounding areas. This type of a system will mirror a sustainable metabolism that is recorded in nature. While the complete accomplishment of the above goal by any city is unlikely, the journey towards such goals will be nonetheless beneficial. The urban centre will thus lower its environmental impact (Girardet, 2008). The research results, however, conclude that the scope of the City's current e-waste management system goes far beyond its geographical area (Chapter 6). Many of the downstream processors, utilized by the large-scale recyclers, are located outside of the local and even provincial area (Chapter 4). While the non-profit sector generally maintains a small radius of distribution, its excess electronic parts are shipped to the above e-waste recyclers. Lastly, the final destination of the e-waste processed by the informal sector is uncertain. Overall, the geographic scope of Toronto's e-waste management network is quite large. Based on the Network Analysis investigation, a large part of the functionality of the e-waste network relies on alliances that extend beyond the geographic boundaries of the City. Only refurbishing of electronics shows potential to impede the broad scale distribution of Toronto's e-waste to adjacent and far away areas. As a result, it can be concluded that as long as large-scale recycling continues to play a dominant role in e-waste processing, completely localized management is beyond the capability of the current system.

In addition to the program's current minimal commitment to e-waste re-use and refurbishing, the effort to reduce the total waste production must also be addressed. An 'ambitious' type of sustainability assessment must attempt to address the underlying cause of the problem (Gibson, 2005). In the case of waste management, waste prevention (through waste minimization incentives, alternative production pathways etc.) must be prioritized out of the three R's (Ackerman, 1997; MacBride, 2011). Waste reduction can be a fundamental solution to urban sustainability. While large scale recycling and re-using display key positive characteristics, without waste reduction strategies they simply represent the reactionary management strategy to an ongoing problem. An exploration of the different urban waste reduction and prevention strategies, as well as potential solutions to a key problem of electronic obsolesce are essential to the dialogue on e-waste management. While they were not largely included in the research conducted as a part of this project, these discussions will serve as excellent sources for future research directions.

The findings from this fieldwork did identify a number of key characteristics that are essential to the development of an environmentally sustainable e-waste management in Toronto. The overall environmental sustainability of e-waste management is greatly affected by the interrelationships between multiple sectors of waste management. Each sector contributes differently to the achievement of a sustainable e-waste management system. While some actors currently play a more dominant role, the presence of others is not as strong. However, based on the review of the key alliances between the different sectors, each one of them is necessary for the creation and support of a resilient and sustainable e-waste management system. Large-scale recycling shows the greatest potential to process the necessary quantity of e-waste produced within the City. However, the mechanical recycling process limits the ability to reuse the valuable minerals and parts of electronic devices. Non-profit refurbishing and informal refurbishing address that shortcoming of large-scale recycling. These sectors redistribute a significant quantity of refurbished electronics locally, thus alleviating negative environmental effects. However, the refurbishing enterprises also rely on the existence of recycling organizations to address their recycling needs. Similarly, an implicit collaboration can be hypothesized to be forming between the informal refurbishers and the City of Toronto Waste Management. Currently, the City's official curbside collection is loosing a portion of its potential economic profit from the collected e-waste to informal scavengers. However, the informal refurbishers have the capacity to reuse and redistribute e-waste locally (Section 5.3). Thus, overall, the environmental sustainability aspects of e-waste management are addressed.

The above relationship between the City and the refurbishing sector could benefit from further research. In theory, a more sustainable distribution of curbside electronic waste may be achieved by encouraging electronic refurbishing. However, at this point two unknowns remain (1) the quantity of curbside electronic waste that could be refurbished (2) the capacity of the refurbishing sector to handle the curbside electronic waste is uncertain. If a stronger partnership could develop between the two actors, the environmental sustainability of the e-waste management sector could drastically increase. Yet, further investigation of the above characteristics of the potential partnership is required.

In the end, a series of useful alliances appear to shape the current electronic waste management system. Within this system, each individual actor is able to positively benefit the environmental sustainability of urban e-waste management. In conclusion, these findings support the promotion of stronger alliances between different sectors involved in e-waste management. The importance of such relationships on the economic and social pillars of sustainability is expressed below.

7.4 Economic sustainability of e-waste management in Toronto

The sustainability of e-waste management also strongly depends on its local economic efficiency. In order to be economically sustainable, a number of factors of e-waste management need to be balanced. Most importantly, electronic waste processing must be economically beneficial to a number of sectors within the management program. The current structure of e-waste management in Toronto deviates from the promotion of that goal. While some of the actors are benefiting more directly from e-waste processing, others appear to be struggling financially. The majority of the financial gain seems to be stemming from large-scale recycling while other sectors struggle to maintain their economic efficiency. Further collaboration between different sectors of electronic waste could promote a more even allocation of economic benefit between the actors.

The benefits of the official municipal and provincial e-waste management program appear to be distributed unevenly between the stakeholders. Formal material recovery can be quite costly to the local municipalities (Scheinberg, 2011; Manhart, 2011). Theoretically, the collection and processing costs of formal e-waste programs should be shared relatively evenly between the stakeholders (government, producers, distributors and consumers). Fieldwork results suggest that in reality the financial cost of collection and processing is mostly allocated between the government, suppliers of e-waste (clients to the recycling and refurbishing organizations) and the consumers. On the other hand, the financial benefit from e-waste processing is reserved for a few local processors.

The results of this thesis have identified large-scale e-waste recycling as the most economically efficient type of e-waste management in Toronto. The mechanized shredding processes yields an array of material components (plastic, metal, glass) that can be sold to downstream processor, thus generating profit. This characteristic has led to a nearly exponential increase of for-profit e-waste processors in Toronto in the recent years (Interviewee #20, August 12, 2013). However, the economic benefit of this type of recycling is often limited to the private organizations themselves. Additionally, as explained in Chapter 4, the structure of the current e-waste program supports the growth of some organizations (OES registered) over the others. As a result, even within the e-waste recycling sector, the financial benefits are divided quite unevenly. Similarly, the economic benefits of electronic refurbishing and reuse could be more widespread. Refurbishing of e-waste can support local economic growth in the communities (Section 4.2.4). Local refurbishing of e-waste yields more technically skilled jobs as well as more local transactions from the sale of second-hand electronics (Williams et al, 2008). However, from strictly financial point of view, electronic refurbishing is more limited in its economic sustainability.

My research results have similarly revealed that refurbishing and reuse of electronics in Toronto CMA are largely limited by their economic efficiency. The economic sustainability of electronic waste refurbishing depends on the market demand for second-hand electronics. A number of actors within the Toronto e-waste network indicated that the interest in refurbished electronics is mainly reserved for old IT items (Interviewee #7, May 31, 2013; Interviewee #20, August 12, 2013). As a result, the majority of the electronic waste items that are currently reused and refurbished in Toronto fall within the IT category. Even so, many companies still find for-profit electronic refurbishing economically unsustainable. Non-profit refurbishing model shows more potential (Chapter 4). The two non-profit electronic waste organizations in Toronto are currently supported through the donations of old electronics from local communities and corporations. As a result, they do not need to pay their suppliers for the provided electronic waste. Additionally, many of the employees at the centres are volunteers or are supported through external funding. These factors allow for an economically sustainable manner to refurbish and reuse electronics. Thus, as of right now, the sustainable economic existence of e-waste refurbishing appears to be largely limited to the non-profit sector in Toronto. At the same time, the non-profit's reliance on outside support yet again points to the importance of alliances between multiple actors within the network.

Collaboration between different sectors could also improve the current valuable material loss in e-waste management. The dominance of the Toronto's e-waste market with large-scale recyclers (Section 6.2 and 6.3), diminishes the reuse of financially valuable materials. As previously mentioned, precious minerals recovered during disassembly can represent a significant portion of the monetary value of e-waste processing (Hageluken, 2006). These materials can be better recovered through manual disassembly and/or reuse. As such, non-profit refurbishing and small-scale entrepreneurs that incorporate manual recycling efforts into their disassembly process act as valuable contributors to the overall economic sustainability of e-waste management. The precious material reuse can in-turn partially alleviate the costs associated with production and mineral extraction. Arguably, the reduction of waste (perhaps by prolonging the life of electronics themselves) can develop the above scenarios even further and drastically reduce the requirements for new materials. However, that kind of monumental change is likely beyond the scope of urban management as it may involve significant political and cultural restructuring. From the local perspective, a more holistic incorporation of various actors into e-waste management could improve the recovery of precious minerals. Overall, contribution from a variety of e-waste processing sectors appears necessary for the economic efficiency of e-waste management.

The economic costs and benefits of e-waste management in Toronto are currently not evenly allocated between multiple actors within the network. The overall economic sustainability of e-waste processing could benefit from the greater incorporation of all stakeholders into the process. At present, large-scale recyclers appear to accumulate the financial benefits directly. Yet, these economic gains are reserved to only a few processors in Toronto. At the same time, small-scale processors; refurbishers and informal scavengers find themselves struggling to survive financially. This distribution of benefits is in-turn obstructing the more diverse sourcing of economic benefits from e-waste.

The refurbishing sectors could promote the recovery of financially valuable materials. Yet, right now they may require support from other actors to enable their existence. An example of such a support system is portrayed in the non-profit refurbishing sector in Toronto. The non-profit organizations benefit from the financial, material and recycling support from other sectors. These enterprises are in-turn able to contribute to the local economy through redistribution of valuable second-hand electronics and creation of jobs. It is recommended that this type of scenario be promoted more strongly within the existing e-waste management system. At the same time, further cost-benefit analysis of the expansion of electronic refurbishing in Toronto could be useful. Currently, the economic efficiency of e-waste refurbishing is largely undermined by the low popularity of second-hand electronics. Systemic issues like pre-planed obsolescence and consumer behavior play a strong role in the future of e-waste sustainability. An in-depth evaluation of these issues could provide the necessary insight into the realistic future of e-waste refurbishing.

7.5 Social sustainability of e-waste management in Toronto

Several aspects of social sustainability can also benefit from a well-developed electronic waste management program. From the social perspective, e-waste management can contribute to the local community by reallocating usable electronics and electronic waste. The collection and processing of old e-waste can act as a source of income and technical training for local residents. Additionally, refurbished electronics can improve the accessibility to computer technology for the local population. In order to meet the above scenarios, a more even allocation of e-waste should be promoted within the urban area. However, the fieldwork results have demonstrated a relatively uneven distribution of access to e-waste in Toronto (Chapter 6). As long as potentially harmful side effects of e-waste processing are addressed, the existing program can strive towards further inclusivity of all the actors within the network.

Greater contribution to the social aspects of sustainability can be achieved through electronic refurbishing rather than recycling. Manual disassembly efforts; waste refurbishing, and informal waste collection create opportunities for technical training and provide residents with supplemental income (Wilson et al, 2006; Gutberlet et al, 2009; Gutberlet, 2012). Currently, these opportunities are supported within the non-profit refurbishing and the informal sector of e-waste management in Toronto. The two non-profit electronic waste refurbishers in Toronto are able to support a large group of technically skilled employees and volunteers. Additionally, the two centres provide training opportunities for their volunteers that can enable them to find better jobs in the future (Chapter 4). Similarly, informal refurbishing often serves as a source of small income to individual 'scavengers' in Toronto (Chapters 5 and 6). Yet, as it has been established during fieldwork, the above sectors are not widely represented within the city. On the contrary, the majority of e-waste is being processed through large-scale mechanical recycling (Figure 6.3). This focus on recycling as the primary disposal route for the provincial and municipal e-waste (Chapter 4) decreases the above social benefits to the local community. While large-scale recycling organizations are necessary to process the large volumes of e-waste, refurbishing and reuse of quality electronics could be developed further.

Electronic waste refurbishing could further benefit local social sustainability by repurposing old electronics for further use by residents. Refurbishing and reuse of electronics locally provides a more accessible source of otherwise not-affordable devices to the local community. While second-hand electronics are more popular in the developing areas of the world, they are still sought after in the developed countries as well (Dyrwal et al, 2000). Through refurbishing, e-waste management can contribute to the decrease of the 'digital divide' (Kahhat et al, 2008; Streicher-Porte et al, 2009). As demonstrated through fieldwork findings, the flow of electronics through non-profit refurbishing and informal processing pathways is best suited for reallocating the second-hand electronics locally (Chapters 4 and 5). The non-profit e-waste refurbishers supply local schools and community centers with necessary IT equipment. Similarly, the informal scavengers redistribute the collected and fixed electronics to the non-profits or individual residents (Chapter 5). This local reallocation of valuable electronics can help improve the more even accessibility to electronics within the local community. Contrastingly, the shredded by-products of mechanical e-waste recycling often find themselves outside of the local community. Moreover, the formal collection and recycling process rarely provides an opportunity to test the functionality of devices (Chapter 5). As a result, some useful electronic devices could be destroyed instead of continuing their life in local schools or households. Overall, from the social sustainability perspective, local reuse and refurbishing or electronics shows the greatest potential. However, as demonstrated above, this processing sector is currently limited by its economic sustainability. Additionally, there are certain health and safety concern that must be addressed.

As previously mentioned, electronic waste does contain a number of potentially dangerous substances, exposure to which could be harmful (Keller 2006; Wath et al, 2010). Adherence to the established health and environmental standards can ensure that the majority of the e-waste produced within the urban area is processed locally in a sustainable manner. While appropriate safety and health standards appear to be in place in most e-waste processing facilities in Toronto, the execution of the standards is varied. The site visits to a number of recycling and refurbishing facilities unveiled large variation of health and safety standards that were practiced during e-waste disassembly, recycling and refurbishing. The use of basic safety equipment (gloves, goggles) was not enforced at all centres equally. Out of all of the processing sites, the large-scale e-waste recycling facilities were identified to have better environmental and health standards in place. The more flexible organizational structure established at some of the smaller facilities affected the execution of safety standards. The health and safety standards practiced by the informal sector could only be hypothesized. In order to address all of the goals of a sustainably managed e-waste system, environmental and health standards must be prioritized equally throughout the sectors. It has been suggested that better incorporation of the more informal sectors into the waste management system could improve their organizational levels (Gutberlet, 2012; Velis et al, 2012). Perhaps through better organization, the necessary safety standards will be better enforced throughout the system. Consequently, more even development and inclusion of individual sectors within the e-waste management system can promote better standards and thus better address social sustainability ideals.

In a similar manner to the environmental and economic goals of sustainable e-waste management, the social aspects can be promoted by a number of currently present actors within the system. From the social sustainability perspective, local e-waste refurbishing and reuse does appear to be more beneficial to the local community. Through local refurbishing more electronics can become accessible to the local population. The availability of lower cost, second-hand devices can aid in the decrease of the 'digital divide'. Additionally, e-waste refurbishing has the capacity to provide local jobs and technical training. The skills gained by individuals through formal or informal refurbishing and reuse can improve their future career opportunities. Refurbishers can also profit from the sale of fixed electronic devices. The above factors clearly support the development of local social equality. However, e-waste refurbishing must also adhere to the necessary health and safety standards to ensure individuals' safety. Currently, the safety standards practiced during e-waste reuse and refurbishing are varied. From that perspective, large-scale e-waste recycling trumps the refurbishing sector. However, it is possible that through stronger integration of each actor within the system, the safety practices will improve.

Further investigation into the social context of e-waste management in developed urban centers is necessary. Research on the types of technical skills and experience gained by refurbishers could demonstrate the need for the increase of e-waste refurbishing and recycling in the city. Similar types of studies are recommended to assess the health and safety protocols within the e-waste refurbishing sectors. If successful, this type of research may be extremely beneficial in future policy and enforcement decisions regarding the municipal management of e-waste.

In addition to the social sustainability goals, the refurbishing and reuse sectors must also address the environmental and economic characteristics of sustainability. Currently, the sectors' ability to process the necessary quantity of e-waste efficiently is questionable. As such, while remaining the most socially sustainable solution for e-waste management, e-waste refurbishing and reuse cannot dominate the market. Thus, in order to adhere to each pillar of sustainability equally, a multi-alliance system that promotes the growth of each sector of e-waste management is proposed as the most currently viable solution to the development of local, urban sustainability.

7.6 Conclusions and recommendations

Local promotion of urban sustainability goals can affect the state of sustainability globally. One of the key factors of local sustainability is waste management (Seadon, 2010). Electronic waste management represents a large and important part of waste management in urban areas, like the city of Toronto. In order to promote the current and future sustainability of electronic waste management multiple aspects of sustainability have to be addressed equally. A truly sustainable e-waste management system can and should promote environmental, economic and social sustainability ideals locally. This study analyzed existing e-waste management's capacity to promote the identified goals of sustainability in the Central Metropolitan Area in Toronto. Five major sectors within the system were identified: (1) provincial government; (2) municipal government; (3) large-scale recyclers; (4) non-profit refurbishers and (5) the informal collectors. Each individual sector has been determined to play a crucial role in the overall strive for sustainability in the City.

The current system of e-waste management in Toronto has been formulated by the activities of the above five sectors. Each actor within the management system has been found to contribute positively to local sustainability. From the economic perspective, the formal management system supporting the large-scale recyclers is the most efficient. Additionally, the relationship formed between the formal government program and the recyclers enables the processing of the largest quantity of e-waste. This makes the alliance beneficial to the environmental aspects of sustainability. From the social perspective, however, refurbishing and reuse of e-waste has greater benefits. However, the state of the market for second-hand electronics hinders the economic efficiency of such enterprises. Yet, the alliance between the non-profit refurbishing enterprises, corporate suppliers, recyclers, government, and informal sector supports the existence of the refurbishing and reuse sector. This successful relationship between multiple actors within the network points to its essentiality. I thus conclude that the development of a sustainable e-waste management system can be achieved through the creation of strong alliances between all of the actors within the network.

A number of topics can provide further ideas for research on e-waste management. The following points provide suggestions for research that will supply key information on the journey to sustainable electronic waste management.

- The economic efficiency of e-waste reuse depends on the popularity of reused and refurbished electronics within the market. Thus, stronger incorporation and expansion of second-hand electronics market in developed urban areas must be assessed. This type of a project will likely involve market and consumer behavior studies.
- Further studies evaluating the contents of curbside and other collected electronics can inform us about the feasibility for the expansion of local reuse efforts. If not enough 'useful' electronics are currently present in the waste stream; other avenues for second-hand product 'harvesting' can be explored. Additionally, the capacity of the e-waste reuse sector to process larger quantity of electronics must be evaluated.
- The social benefits tied to e-waste reuse and refurbishing industry can be analyzed as well. The types of skills, experience and opportunities provided for individuals within the reuse sector can provide a different dimension to the conversations about sustainable waste management practices in urban centers.
- From the long-term sustainability perspective, the barriers to waste reduction over waste recycling or reuse must be understood better. It is likely that waste prevention, in the form of reduction of obsolescence and changes in consumer behavior, is intrinsically tied to the political and economic structure of our society. As such, as it was proposed by Gibson (2005), a more politically minded assessment of sustainability is likely necessary for the promotion of a truly resilient management system.

Additionally, the interrelationship pattern between different sectors of e-waste management could benefit from more research. More geographically diverse conclusions could have a stronger impact on policy and planning. In turn, the promotion of more even integration of sectors into waste management can benefit local and global sustainability.

While maintaining the focus on e-waste recycling and reuse is important, stronger efforts need to occur to prevent waste production in general. Truly sustainable e-waste management on municipal, provincial, national and international levels is 100% reduction in electronic waste. The path towards that goal is likely beyond the scope of municipal management systems. Key electronic producers must commit to changing their current attitude towards electronic item obsolescence and promote product reuse instead. While local stakeholders' role on the total modification of the system is limited, there are some steps that can be undertaken by consumers and local organizations. Consumers have a choice when it comes to purchasing electronic devices. A decrease in our current fascination with "the new and exciting" and an increase in sustainable (i.e. second-hand) product purchasing can greatly improve the current situation. Similarly, larger-scale organizations can focus on reusing the slightly older models of electronics rather than purchasing brand new ones. While these types of changes will unlikely solve all of the unsustainable e-waste production and management practices, they can greatly contribute to our common journey for a sustainable future.

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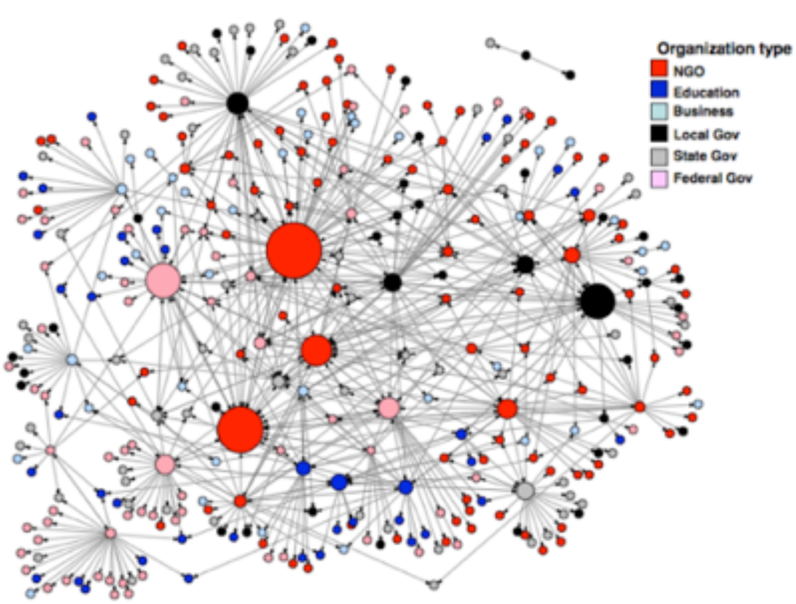
Appendix I: Fieldwork Questionnaires

Social Network Analysis Questionnaire

The following questionnaire is a part of a Master's Thesis project, under the supervision of Dr. Josh Lepawsky at the Memorial University of Newfoundland. This project will contribute to the knowledge about the function of the electronic waste management system in an urban setting, such as the City of Toronto. The findings from this study may result in an improved understanding of the sustainability of the current system as well as identify the necessary steps for improvement, if at all necessary. As waste management is a necessary part of everyday life for ordinary citizens, this study can provide beneficial knowledge to all of its participants.

This particular questionnaire is designed to collect information for a Social Network Analysis of the electronic waste management sector. Social Network Analysis is a methodology used to depict the structure of relationships between individuals in a network (city, organization, neighbourhood). This type of Analysis is useful to help understand not only the relationships themselves but how these interactions govern the decision making process, which in this case would affects the allocation of electronic waste between multiple actors (recycling organizations, government and small scale entrepreneurs etc) in a network. Recently the use of SNA has become relatively popular in the field of natural resource management. The following visualization is an example of Social Network Analysis.



Thank you for your participations. The following questionnaire is estimated to take up approximately 20 minutes of your time. Please do not hesitate to ask any questions while completing the questionnaire.

1. Please provide your name, title and the name of the organization that you work for.

2. What are your organization's annual material inputs and outputs for the past 3 years (in tonnes or number of units)? If possible, please indicate the general types of materials for both.

	Tonnage/ Quantity	**Type of material (app. %)**
2010 Input		
2011 Input		
2012 Input		
2013 Input		

	Tonnage/ Quantity	**Type of material (app. %)**
2010 Output		
2011 Output		
2012 Output		
2013 Output		

3. Please list the top ten sources of the material **inputs** for your organization that are **located within the Greater Toronto Area** (e.g. Federal Government, Provincial Government Schools, small local businesses). If possible, please indicate the approximate quantity of material for each.

e.g. Toronto Schools (30 tonnes per year or 300 computers, some printers + other material)

1.

2

3.

4.

5.

4. Please list the top ten **outputs** of the material that is processed at your facility (Local community centres, Local smelter, Local school). If possible, please indicate the approximate quantity of material for each.

e.g. A local community centre (1 tonne or 10 computers per year)

1.

2.

3.

4.

5.

5. Please list the **organizations or individuals** (that were not previously mentioned) that you **collaborate** with while managing electronic waste.

“Collaboration” is considered to be any kind of an interaction inside or outside of a work setting that is related to electronic waste management. Please indicate the nature of a collaboration that you share with an individual/ organization (e.g. an organization/ individual can act as your source of funding, can be involved in an annual audit, can act as a source of regulation etc.)

E.g. Ontario Electronic Stewardship (source of regulations)

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14…

Electronic waste management survey

As a part of my Master's project, I am analyzing the electronic waste management system in Toronto, ON. This questionnaire is designed to provide information on the type of work, skills and background necessary to work/ volunteer in the electronic refurbishing/ re-use sector.

Your participation in this survey is highly appreciated. While filling out the questionnaire you are welcome to ask any questions or omit a question.

1. Please specify your age group
   a. under 18
   b. 18 - 24
   c. 25 - 30
   d. 30 – 40
   e. 40 and over

2. Please identify your highest level of education
   a. Less than high-school diploma
   b. High-school diploma
   c. Some college or associate degree
   d. Bachelor's degree
   e. Advanced degree

3. How long have you been working at this facility?

a. Less than 1 month
b. Less than 6 months
c. 6 months – 1 year
d. 1 – 2 years
e. 2 – 4 years
f. 5 or more years

4. How many hours a week do you usually spend at the facility?

a. under 5 hours
b. 5 – 10 hours
c. 10 – 20 hours
d. 20 – 30 hours
e. 30 – 40 hours
f. more than 40 hours

5. Do you have a background working with electronic equipment or in the IT industry? If yes, please specify.

6. How many items do you process during a regular working day?

7. What duties do you perform on regular basis at this placement?

8. Do you have a computer at home? If so, what type and model.

9. Where did you purchase/ obtain your personal electronics (please indicate all that apply)?

a. Large department store (Walmart, The Bay etc.)
b. Large electronic stores (Best Buy, Future shop)
c. Small electronic stores
d. Non-for profit organizations (Computers for School, Free Geek)
e. Second- hand stores (Value Village, Goodwill)
f. Other (please specify)

10. Why do you participate in recycling/ refurbishing of electronics?