Evaluating the contribution of cooperative sector recycling to the reduction of greenhouse gas emissions: An opportunity for recycling cooperatives in São Paulo to engage in the carbon credit market

by

Megan Frances King
B.A., University of Victoria, 2009

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Supervisory Committee

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Dr. Jutta Gutberlet, Supervisor (Department of Geography)

Dr. Aleck Ostry, Departmental Member (Department of Geography)

Abstract

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Dr. Aleck Ostry, Departmental Member (Department of Geography)

Greenhouse gas emissions can be reduced through recovery and recycling of resources from the municipal solid waste stream. In São Paulo, Brazil, recycling cooperatives play a crucial role in providing recycling services including collection, separation, cleaning, stocking and collective sale of recyclable resources. The present research attempts to measure the greenhouse gas emission reductions achieved by the *Cooperpires* recycling cooperative, as well as highlight its socio-economic benefits. Methods include participant observation, structured interview, a questionnaire, and greenhouse gas accounting of recycling using a Clean Development Mechanism methodology. The results afford an exploration of the opportunity for *Cooperpires* and other similar recycling cooperatives to participate in the carbon credit market.

Table of contents

List of tables

List of figures

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Dedication

This thesis is dedicated to the members of the *Cooperpires* recycling cooperative in gratitude for their collaboration on this research project, and in recognition of their environmental stewardship and inspiring solidarity.

And, to my husband, Thiago Silva, who has been my guide in Brazil, my teacher (Portuguese and *R*), my translator, and my pillar of strength throughout these last 3 years.

1. Introduction – Municipal Solid Waste: A Challenge for Cities, Citizens, and the Environment

The world has experienced unprecedented urban growth in recent decades. Currently, three-quarters of the world's total urban population lives in low- and middle-income nations of Africa, Asia and Latin America (Cohen, 2004; Medina, 2010; Satterthwaite, 2003; Population Reference Bureau, 2011). The rates of production, consumption and disposal of plastic, paper, glass, metal, and organic materials, as well as the management of these material flows, are key components in the environmental sustainability and public health of these growing urban environments and their surrounding sub- and peri-urban regions (Satterthwaite, 2003). Many cities, especially mega-cities like São Paulo, Brazil, "[face] many environmental and ecological problems associated with rapid industrialization and population growth" (Cohen, 2004, 23). Such problems include a rising municipal solid waste generation rate and the necessary management of this material flow. In many low- and middle-income world cities, socio-economic conditions – rapid population growth, lack of sufficient funds, expensive services, and high proportion of low-skilled workers among labour force (Forsyth, 2005) – along with increasing industrialization and urbanization overwhelm municipal government resources available for managing the growing amounts of solid waste. Many municipalities are currently struggling to extend adequate solid waste management services – collection, diversion, and sanitary treatment and sanitary disposal – for their entire populations (Barton, Issaias & Stentiford, 2008; Decker, Elliott, Smith, Blake & Rowland, 2000; Shekdar, 2009; Uiterkamp, Azadi & Ho, 2011; Wilson, Velis & Cheeseman, 2006).

The essential nature of solid waste management places the responsibility for its delivery "within the public domain as a public good. Because [solid waste management] is an urban issue, the level of government responsible is typically

TABLE 1. Rates of Municipal Solid Waste (MSW) Collection, Landfill Disposal, Informal Recycling, and Number of Informal (Cooperative) Recyclers.

Source	City, Country	MSW collected, % of waste generated	Landfill disposal, % of MSW waste collected	Informal sector recycling rate, % of recyclables	Number of informal (cooperative) recyclers
Uiterkamp, et al., 2011	Delhi, India	70-80%	91%	17%	80,000 – 100,000
	Dar es Salaam, Tanzania	48%	89%	11%	600
Henry, Yongsheng & Jun, 2006	Nairobi, Kenya	30-45%	100 %		~300,000 ‡
Scheinberg, Spies, Simpson & Mol, 2010	Pune, India			22%	
	Lima, Peru			20%	17,000
Wilson, et al., 2006	Cairo, Egypt			80%	60,000
Wilson, Araba, Chinwah & Cheeseman, 2009	Manila, Philippines			16.4%	
Sembiring & Nitivattananon, 2010	Bandung, Indonesia	56.8%	100% §	47%	3000
Fundação Nacional da Saúde (FUNASA), 2010	São Paulo, Brazil	99.5% α	90%	(1%) φ	20,000 (1,852) φ

‡ Number of informal workers in the MSW management sector including recovery/recycling. Source: Mérino, 2010; § Source: Sundana, 2006; α Percentage of municipal population receiving MSW collection service; φ Recycling rate accomplished by recyclers' 15 cooperatives active in the municipality.

[municipal] government" (Cointreau-Levine, 1994, 1). Yet, a wealth of research on municipal waste management practices in low- and middle-income countries have shown that in many of the cities studied, government provision of municipal solid waste management services is often limited, and does not extend to all urban residents, as illustrated above in TABLE 1. Waste collected by the municipal authorities can be as low as 30% (Nairobi, Kenya; Henry, et al., 2006). The most frequently cited factors contributing to inadequate and inefficient municipal solid waste service provision are outlined below, in TABLE 2. Coupled with the extremely high cost of municipal SWM services (Barton, et al., 2008), these factors severely undermine the environmental sustainability and public welfare. Failure to provide waste management services and extend their provision to the entire population threatens public health and ecological integrity (Baud, Grafakos, Hordijk & Post, 2001; Gutberlet 2010; Satterthwaite 2003; Uiterkamp, et al., 2011). These threats, as well as the economic, human and social resources required for waste management programs are among the many concerns surrounding ever-increasing municipal solid waste generation (Barton, et al., 2008; Baud, et al., 2001; van de Klundert & Lardinois, 1995; Troschinetz & Mihelcic, 2009). Troschinetz & Mihelcic (2009),

TABLE 2: Factors contributing to inadequate and inefficient municipal solid waste management

Source	Municipal solid waste management barriers
Henry, et al. 2006; van de Klundert & Lardinois 1995; Memon, 2006, 2010; Shekdar 2009; Talyan, Dahiya & Sreekrishnan, 2008; Uiterkamp, et al., 2011	Low priority given to and/or inadequate funding available for solid waste management
Buenrostro 2003; Noel, 2010; Memon, 2010; Troschinetz & Mihelcic, 2009	Lack of effective solid waste management planning, policy enforcement, administration and regulation
Noel, 2010; Troschinetz & Mihelcic, 2009	Shortage of trained personnel and human resources allocated to municipal SWM
Baud & Post, 2004; Henry, et al. 2006; Median 2000; Talyan, et al., 2008	Illegal urban settlement, and deficient physical infrastructure and equipment
Baud & Post, 2004; Bhuiyan, 2010; Kironde & Yhdego,1997; Mérino 2010	Corruption and unaccountability, resulting in poor urban governance

whose study of 23 low- and middle-income countries – including Bhutan, Botswana, Brazil, China, Guyana, India, Indonesia, Iran, Jamaica. Loa, Lebanon, Malaysia, Maldives, Mauritius, Mexico, Mongolia, Nepal, Philippines, Sri Lanka, Thailand, Turkey, Turkmenistan, and Vietnam – found that for 77% of them, inadequate or unreliable government financing of municipal solid waste management operations is a barrier to the implementation of recycling schemes. The lack of recycling programs further exacerbates threats to environmental sustainability and public welfare (Gutberlet 2011a, b).

Changing society's consumption patterns to reduce the amount of municipal solid waste generated is, the most significant waste management activity towards mitigating threats and costs associated with municipal solid waste. Once waste is generated, however, diverting the recyclable resources away from landfills and dumpsites and recycling them back into the product chain is the environmental and social "best practice" for the following reasons. For most types of recyclable materials, their recycling results in energy and resource efficiency (Lino & Ismail, 2011; Pimenteira, Pereira, Oliveira, Rosa, Reis & Henriques, 2004); the reduction of greenhouse gas emissions related to virgin resources extraction and manufacturing; and the avoidance of landfill disposal of biodegradable waste (Donovan, Jilang, Bateson, Gronow & Voulvoulis, 2011; Eriksson, Reich, Bjorklund, Assefa, Sundqvist, Granath, et al., 2005). Benefits of recycling accrue to the whole of society with greater public health (Memon, 2010), enhanced quality of life (Baud, et al., 2001) and livelihood opportunities (Gutberlet 2011a; Schenck & Blaauw, 2011; Noel, 2010).

1.1 Research Questions

Informal/cooperative sector resource recovery and recycling, when supported as an integral part of a municipal waste management system, enhances the system's sustainability through the creation of natural, social, human, physical and financial capitals (i.e., resources) (Baud, et al., 2001; Najam, Rahman, Huq & Sokona, 2003;

Rogger, Beaurain & Schmidt, 2011). The current research looks specifically at the resource recovery activities of the cooperative recycling sector and their roles in and 'triple bottom line' sustainability of municipal waste management and climate change mitigation, as well as poverty alleviation in a municipality of São Paulo, Brazil.

The questions to be answered by this research are:

1) What contribution does cooperative sector recycling make towards greenhouse gas emission reductions and climate change mitigation?
2) What contribution does cooperative sector recycling make towards the formal, integrated municipal solid waste management system in a municipality of São Paulo, Brazil?
3) How does cooperative sector recycling contribute towards social inclusion and poverty alleviation?

To answer these questions, the research studies one recycling cooperative in Ribeirão Pires, Brazil, using a mixed methods approach including participant observation, structured interviews, questionnaires, material flow assessment, and energy and greenhouse gas emissions accounting.

A broad overview of the context within which these questions are considered is given in the following section, chapter 2, *Integrating Recycling into Solid Waste Management*, discussing waste management and informal/cooperative sector recycling in low- and middle-income countries, and specifically, in Brazil. The purpose of framing the current discussion in terms of country income level is to situate Brazil and the city of São Paulo within the global landscape of municipal solid waste management practices, the types and extents of which are influenced by the national and municipal gross domestic product (GDP) of each country (Brunner & Fellner, 2007). This situated-ness enables a comparison between São Paulo and other cities of similar conditions with respect to their municipal solid waste management systems. The most salient similarity and point of comparison is the

extent to which the informal/cooperative sector participates in municipal solid waste management activities and particularly resource recovery and recycling in São Paulo and other cities.

Chapter 3, *Waste, Recycling and Greenhouse gas emissions*, considers the greenhouse gas emissions related to waste, how recycling mitigates these emissions, the various ways greenhouse gases emission reductions can be measured, and the role of the Clean Development Mechanism in municipal solid waste management, climate change mitigation, and sustainable development. The *Methods* section follows in chapter 4, describing the greenhouse gas accounting method chosen to measure the emissions reductions achieved by the resource recovery activities of *Cooperpires*, the recycling cooperative on which this study is based. Additionally, the qualitative methods employed in this research – participant observation, structured interviews, and questionnaires – are described. In chapter 5, *Findings and Discussion,* the environmental, social and economic benefits of *Cooperpires* recycling cooperative are discussed in terms of the various capitals inherent in, and created through, cooperative recycling when it is supported by policies, partnerships, and public participation. Also discussed is the potential for *Cooperpires* to engage in the carbon credit market.

1.2 Defining Waste and Recycling

To proceed in this discussion, it is necessary to first clearly define the use and understanding of the term and concept of *waste*. The understanding of *waste* varies across cultures, generations, socio-economic strata, and economic activity; however, the common public, academic, and political use of the term *waste* refers to any material or product that is viewed as unsanitary (Kennedy, Cuddihy & Engel-Yan, 2007), and as "worthless or unused for human purpose… the spent and valueless material left after some act of production or consumption" (Lynch, 1990, 146). Humans' common psychological and emotional responses to waste are negative (O'Connell, 2011), and result in an attempt to distance ourselves from it by

disposing of it in a landfill or by incineration. My own understanding of *waste* mirrors that of the recyclers who participated in this study, differing from the common conception in that it has a much narrower definition, referring only to a product or material that has completely expended its use value and is devoid of any further utility. This interpretation of waste excludes any material output of the production process, or a post-consumer product, that is recyclable (or re-usable, for that matter), which, in this text, is referred to as a *resource*. Therefore, while the use of the term *waste* throughout this text refers to the most common understanding, it is used with the intention of demonstrating that much of the material we call *waste* is not actually waste at all, but a source of valuable recyclable resources.

Accepting van Beukering and Bouman's (2001) definition, *recycling* is a collective term for 1) the recovery of recyclable resources from the waste stream, either at the disposal site, or by door-to-door collection; and 2) the utilization of secondary material, i.e., the reintroduction of the recovered materials into the product chain, to be manufactured into new products. Pokharel and Mutha (2009) describe the term *reverse logistics* as encompassing *recycling*, as well as the process of moving recyclable resources from the point of collection (the point of discard, be it household, business establishment, street, landfill or dump), through separation and consolidation (these are the main activities of the informal / cooperative sector recyclers), and finally to remanufacturing. *Reverse logistics* and *recycling* are synonymous to a large extent, but *reverse logistics* also includes the consolidation and transportation of recyclables, and their re-introduction into the product chain (Pokharel & Mutha, 2009). Reverse logistics and recycling are what I refer to collectively as the *recycling actor network.* This term is helpful in understanding the theoretical background of this research, discussed in chapter 4.

Recycling is about reducing consumption of energy and natural resources. Recovering recyclable resources from the waste stream, diverting these materials away from the landfill, dumpsites and incinerators; adding value through separation and commercialization; and finally, remanufacturing – reintroducing the recyclable

materials back into the product chain – mitigates the environmental, economic, and social impacts of waste generation and disposal, be that in a landfill or by incineration, for most materials (Björklund & Finnveden, 2005; Morris, 2005).

1.3 Focus on Brazil

Brazil is South America's most influential country and a rising global economic power (BBC News 2012). It is also the most populous with 190.7 million inhabitants. Brazil is currently an upper-middle-income country (The World Bank, 2012) that has throughout the past four decades experienced rapid industrialization, urban expansion and population growth, globalization, and a burgeoning consumer culture (Taschner, 2000) – factors that lie at the root of overwhelming municipal solid waste challenges.

1.3.1 Current Municipal Solid Waste Management Services

Today, almost 80% of all Brazilian municipalities are covered by waste collection services, provided by the municipal authority's own personnel, or private firms under contract, or a combination of the two. In the Southeast region of Brazil (where São Paulo is located), service coverage for regular municipal solid waste collection ranges from 24.9% to 100% of the population; the average is 93.4%. The lowest rates of coverage mainly occur outside the Metropolitan Region of São Paulo (National System of Information on Sanitation [*Sistema Nacional de Informações sobre Saneamento*; SNIS] 2011). Within the Metropolitan Region of São Paulo, coverage of services can be as low as 83.5% of the population, but the average rate is 99%. The city of Ribeirão Pires, where this current research is situated, has 98.5% coverage (National Foundation of Health [*Fundação Nacional da Saúde*; FUNASA] 2010).

Appropriate final disposal of municipal solid waste and a low recycling rate continue to be a problem in Brazil. The total collected municipal solid waste in Brazil is estimated between 63.4 and 67.1 million tonnes per year (Brazilian Association of

Public Cleaning and Special Wastes Companies [*Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais*; ABRELPE], 2010; SNIS, 2011), with 61% of municipalities making use of inadequate waste disposal sites (ABRELPE, 2010). The Brazilian Institution of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2008) reports that nationally, approximately 64.6% of MSW is deposited in sanitary landfills, 15.7% is disposed in controlled landfills, and 17.6% goes to open dumps; 1.2% is recycled; and less than 1% is composted or incinerated. For cities the size of Ribeirão Pires (100,000 – 300,000 inhabitants; population density greater than 80 inhabitants/km^2), just over 84% of municipal solid waste is deposited in sanitary landfills, 11% is disposed in controlled landfills, and only 3.2% ends up in open dumps; 1.0% is recycled; and less than 1% is composted or incinerated. Fortunately, Brazil's new federal waste management policy, National Policy on Solid Wastes (*Política Nacional de Resíduos Sólidos*) Law Nº12.305/2010, has recently demanded the closure of all uncontrolled waste dumps, and their replacement with sanitary landfills by 2014.

1.3.2 Municipal Solid Waste Management Expenditure

Following research conducted by ABRELPE (2007, 2008) and IBGE (2007, 2008), the average amount of financial resources invested by Brazilian municipalities into urban cleaning activities including waste collection and disposal is R$ 8.93 per inhabitant/month. This expense is equivalent to US$ 107.00 per capita/year, eight times the expenditure on municipal solid waste management services in São Paulo in 1989 – US$ 13.32 - and even exceeding New York City's 1991 expenditure on such services, US$ 106.00/year (MacFarlane 1998). Collection services alone receive 36.8% (R$ 3.29/month) of the budget. Brazilian municipalities could save from 3% to 12% of the annual budget if all recyclable resources are diverted from the waste stream (Grimberg, 2007).

The Brazilian Institute of Applied Economic Research (*Instituto de Pesquisa Econômica Aplicada* [IPEA], 2010) reports that, among 204 Brazilian municipalities, the average cost of regular municipal solid waste collection in 2007 was R$ 80.24

per tonne of waste. The average cost of public or privately administered formal sector selective collection of recyclables is R$ 215.59 per tonne, yet the cost to municipalities for selective collection administered by recycling cooperatives is R$ 80.00 per tonne. Municipalities make substantial savings of an estimated R$ 135.59 per tonne of municipal solid waste collected by contracting the selective collection service to the informal/cooperative sector recyclers. However, such a dramatic reduction in cost is likely due to the exploitation of recyclers' cheap labour, a situation that is not ideal and should be ameliorated through equitable partnerships between municipal authorities and recycling cooperatives in which the recyclers are fairly remunerated for their work.

1.3.3 Recycling Services

ABRELPE's 2010 report, *Panorama dos Resíduous Sólidos no Brasil – 2010* shows that the prevalence of recycling initiatives among the 5,565 municipalities in Brazil is 57.6%, increasing to 79.5% among municipalities in the Southeast region. For municipalities with populations the size of Ribeirão Pires' (100,000 – 499,999), the prevalence is 84%. Initiatives usually involve the installation of voluntary delivery posts, and may also involve the formalization of agreements with recycling cooperatives for the provision of selective collection services, as is the case for 59% of municipalities in the Metropolitan Region of São Paulo, but only 6.4% of all Brazilian municipalities (FUNASA, 2010). Clearly, elective collection in the country is still in its infancy, representing only 2.4% of collected municipal solid waste – 0.02 kg/capita/day of municipal solid waste is recovered across all Brazilian municipalities (IPEA, 2010; SNIS, 2011). Selective collection service providers include the municipal authorities (25%), private companies contracted by the municipal authorities (45%), and recycling cooperatives or associations receiving municipal support (29.7%). Difficulties in offering this service include the lack of suitable location for triage of recyclable resources, poor acceptance by the community, and the lacked of an awareness campaign (IBGE, 2002; FUNASA, 2010)

A case study by Lino & Ismail (2011) observed a modest door-to-door selective collection program in the city of Campinas, São Paulo, run by the municipal administration in partnership with a recyclers cooperative. It diverted from the landfill 20 tonnes/month [0.67 tonnes/day] of dry recyclables, achieving a recovery rate of 1.5% of municipal solid waste produced. For aluminum cans, however, Brazil's national recycling rate is over 98%, surpassing even the world leader in recycling, Japan (~93%; ABRELPE, 2010; United Nations [UN], 2010).

There are an estimated 20,000 informal/cooperative recyclers in the Metropolitan Region of São Paulo (FUNASA, 2010; Grimberg, 2007), and 80,000 – 1,000,000 in all of Brazil (National Movement of Collectors of Recyclable Materials [*Movimento Nacional de Catadores de Materiais Recicláveis*; MNCR], 2010). Their efforts stimulate growth of local industry and the local availability of materials, creating jobs and revenue (ABRELPE, 2008, 2010; Fehr & Santos, 2009; Gomes & Nóbrega, 2005; Gonzenbach & Coad, 2007; Mancini, Nogueira, Kagohara, Schwartzman & Mattos, 2007). As these authors make clear, the imperative to extend collection services to all members of rapidly-growing urban populations means that many employment opportunities can be found in resource recovery and recycling, from the collection of materials to the remanufacturing of new, recycled-content products as well as the reverse logistics industry.

2. Integrating Recycling into Solid Waste Management

2.1 Overview

With increasing environmental awareness, the last four decades have seen developed countries around the world implement national and sub-national policies and strategies in line with a 3R (reduce, re-use, recycle) approach (Rodic, Scheinberg & Wilson, 2010; Bogner, Pipatti, Hashimoto, Diaz, Mareckova & Diaz, 2008; UN 2010), often referred to as *integrated solid waste management* (Memon, 2010). Many researchers and waste management policy-makers consider the 3R approach as the front line strategy against a growing waste generation and disposal

burden. The definition of *integrated solid waste management* is the integration of all waste management related activities under one cohesive system. This trend emerged in high-income countries in the 1980s (Rodic, et al., 2010; Sakai, Sawell, Chandler, Eighmy et al., 1996), and in middle-income countries like Brazil, Indonesia, and the Philippines in the 1990s (Furedy, 1997; Rodic, et al., 2010). Unfortunately, in many cities – especially in European countries (Organization for Economic Cooperation and Development, 2008) – integration of solid waste management systems appears to be accompanied by an upward trend in the prevalence of higher technology activities, such as incineration and waste-to-energy, as solutions to growing volumes of waste and decreasing landfill space (Gutberlet 2011a, b). These technologies are expensive, provide far less employment opportunities (Cointreau-Levine, 1994; Gutberlet 2011a, b) and often not appropriate to local conditions such as waste composition (large biodegradable fraction with high water and low heat content) prevalent in low- and middle-income countries (Nas & Jaffe, 2004; Rogger, et al., 2011). Furthermore, waste-to-energy is not an energy efficient technology, supplying only 30% energy conversion efficiency (Rigamonti, Grosso & Giugliano, 2009).

In cities where the formal sector does not yet provide such services, a niche is often filled by the informal/cooperative sector where integrated solid waste management can serve not only an environmental function, but also as a poverty alleviation strategy (Gutberlet 2010, 2012; Forsyth 2005; Noel, 2010; Schenck & Blaauw, 2011; Scheinberg, et al., 2010; Sembiring & Nitivattananon, 2010). Filling this gap in waste management service is much to the benefit of the municipal government (Barton, et al., 2008; Talyan, et al., 2008) and the reverse logistics industries (Agarwal, Singhmar, Kulshrestha & Mittal, 2005; Fehr & Santos, 2009; Wilson, et al, 2006); especially the informal/cooperative recyclers themselves, whose livelihoods depend on collecting and commercializing the recycling resources.

For these reasons, the 3R approach to integrated solid waste management is

more affordable and more appropriate for low- and middle-income country cities as it decreases the reliance on landfills for disposal, and instead valorizes the materials as resources to be re-introduced (*recycled*) into the industrial product chain (Scheinberg, et al., 2010; Wilson, et al., 2006), driving the reverse logistics industry, including remanufacturing – all an important sources of employment (Agarwal, et al., 2005; Fehr & Santos, 2009). Integration of recycling also valorizes the work of informal sector recyclers and their contribution to the communities (Gutberlet & Jayme, 2010), and provides livelihood opportunities for many of the urban poor (Gutberlet 2012). The Energy and Resources Institute (2006) report that, as a result of informal sector recovery of recyclable resources, local recycling markets in India are experiencing an annual growth rate of 12% to 15%, In Brazil, the number of companies that recycle plastics grew by almost 61% between 2000 (7,003 companies) and 2009 (11,526 companies; ABRELPE 2010). Lino & Ismail's (2011) study reports that among individual retailers of recyclables in the city of Campinas, there exists fierce competition for recyclables resources.

2.2 Informal and Cooperative Sector recycling

Masocha (2006) defines the informal sector as "any process of income generation unregulated by the institutions of the state and those who engage in such activities do not pay direct tax either to the local or central government" (839). The cooperative sector refers to groups of recyclers that have organized into cooperatives, which may be legalized and which sometimes work in partnership with municipal authorities or other organizations. The cooperative sector is *semi-formal* in nature and, in Brazil, has been categorized as part of the *solidarity economy* (Dias & Alves, 2008; Gutberlet, 2012). Cooperative recyclers may receive remuneration from their municipal government partners, e.g., per tonne of material diverted from the landfill (Gutberlet, 2011). They may also pay taxes and social security, and receive benefits such as healthcare, technical training and literacy courses, protective uniforms, baskets of food staples and bus vouchers, and tax exemptions (Dias & Alves, 2008; FUNASA, 2010).

Resource recovery – the collection, separation and commercialization of recyclables recovered from the waste stream – is a widespread informal sector activity. It is a survival strategy of the most socio-economically excluded segments of society (Gutberlet, 2009). It is often the case that the people working in the informal/cooperative sector are socio-economically excluded, usually because of a low level of education and lack of qualifications, or advanced age (Talyan, et al., 2008; Schenck & Blaauw, 2010). They are discriminated against (Medina, 2000; Sembiring & Nitivattananon, 2010; Taylor, 1999), working in precarious and unsafe conditions, with inadequate infrastructure, lack of space, shelter, and basic sanitation. Recyclers face daily risks of infection, respiratory illness, cuts and musculo-skeletal (heavy lifting, repetitive stress, or acute trauma) injuries (Baud, Grafakos, Hordijk & Post, 2001; Gutberlet & Baeder, 2008), and constant stress due to the economic uncertainty and precariousness of working in the informal/cooperative sector (Gutberlet, 2008).

The work carried out by the informal sector can be labour-intensive (Agarwal, et al., 2005; Sembiring & Nitivattananon, 2010; Wilson, Et al., 2006), involving collection on foot using push-carts in areas where access to houses and businesses is restricted for motor vehicles; manual separation of recyclables from wastes; heavy lifting, loading and unloading, and intensive manual sorting. However, such methods are often more appropriate to local conditions, more reliable, and more affordable (Sembiring & Nitivattananon, 2010:803). Scheinberg, et al. (2001) argue that the informal recycling sector is highly skilled at identifying wastes with potential value. They collect materials they have been discarded as waste and add value to them by sorting, cleaning, altering the physical shape to facilitate transport or by aggregating materials.

Gutberlet (2009, 2010) observes that a growing number of informal sector recyclers are organizing into associations or cooperatives and sometimes receive support from NGOs or government. This is now the case in Brazil as of 2010 when Decree 7405 was enacted, establishing the Programa Pró-Catador (Pro-collector

Program; *collector* refers to informal/cooperative recycler). This federal program is intended to support and promote the organization of informal recyclers, to improve their work conditions, increase their opportunities for social and economic inclusion, and expand selective collection services in the country through employment of the informal/cooperative sector. Additionally, the Brazilian National Policy on Solid Waste – *Política Nacional de Resíduos Sólidos* – also enacted in 2010, legislates the inclusion of formalized recycling cooperatives and associations in the formal SWM system (Ministério do Trabalho e Emprego - Secretaria Nacional de Economia Solidária (MTE-SENAES], 2011)

Whatever the organizational form, or the extent of socio-economic integration, those that perform resource recovery (selective collection) and recycling activities fulfill the role of "environmental agents" (Fehr & Santos, 2009, 281), or "environmental stewards" (Gutberlet & Jayme, 2010, 3340). Although the focus of this study is a newly formalized cooperative, the discussion applies as well to those groups of organized recyclers that are part of the informal sector. As Nas & Jaffe (2004) point out, the heterogeneity of waste management systems, either formal or informal, makes delineation difficult. The organizational forms are often mixed or overlapping (Dias & Alves, 2008; Gutberlet 2009; van de Klundert & Lardinois 1995; Masocha 2006; Nas & Jaffe, 2004), existing anywhere along multiple spectra of size, geographic scale, sector, association, integration and governance, illustrated in FIGURE 1.

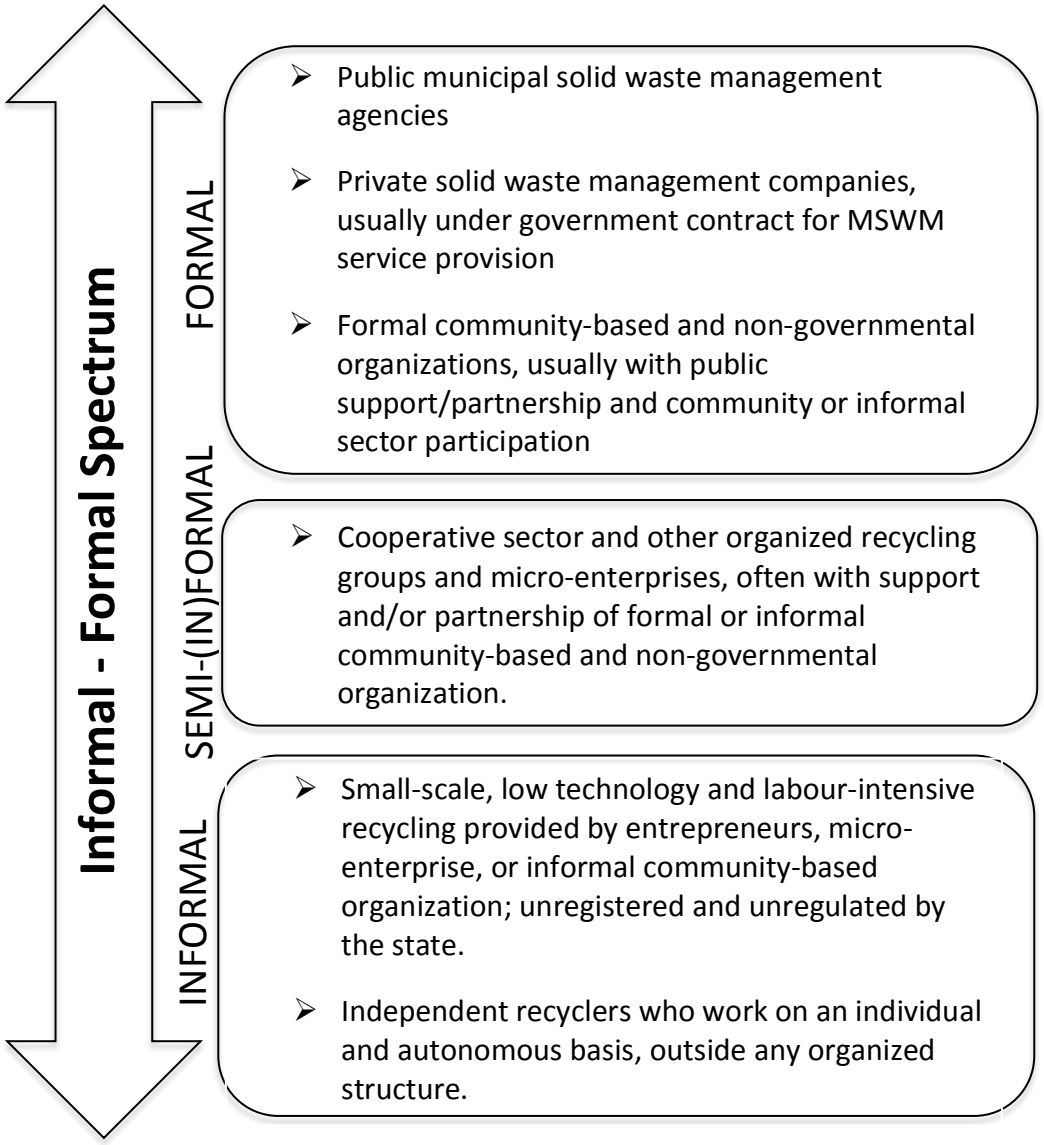


FIGURE 1. Spectrum of informal to formal solid waste management service providers.

An overwhelming number of studies can attest to the efficiency with which informal and cooperative sector recyclers are providing this necessary environmental service in various cities across the world, as illustrated in TABLE 1. Wilson, et al. (2006) state that the informal sector is a "rather efficient component of the existing recycling system", citing the Zabbaleen recycling community in Cairo,

Egypt, as a prime example. Scheinberg, et al. (2010) demonstrates that such efficiency can be seen not only in Cairo – where the Zabbaleen achieve an annual resource recovery rate of 64% -- but also in Pune (India) where the municipal authority's local partner in solid waste management is KKPKP, a union of informal recyclers representing the city's 10,000 informal sector recyclers, most of whom are women. In Cairo and Pune, as well as in Lima (Peru), and Quezon City (Philippines), the resource recovery rate by the informal sector is between 20 – 80% (24% for Pune, and 80% for Cairo, according to Wilson, Et al., 2006). And, in Delhi, India, the informal sector is responsible for 15 - 20% of MSW recycling (Chaturvedi, 2009; Talyan, et al., 2008). These rates are comparable to the annual recovery rates for developed countries with recycling schemes integrated into their formal waste management systems: Republic of Ireland from 2004 to 2008 (~23%; McCoole, Derham, Kurz & McDonagh, 2011), Czech Republic in 2008 (24%; Ministry of the Environment of the Czech Republic, 2009), and the early-adopters of municipal recycling, Canada (22%; Organisation for Economic Cooperation and Development [OECD], 2001) and the USA (27.3%; Franklin Associates, 1997) for 1996.

In spite of their efficiency, knowledge and resourcefulness, entrepreneurship, innovation, and adaptability, public and institutional attitudes towards informal recyclers are generally negative; recyclers are frequently harassed and stigmatized, and policies tend to be neglectful, repressive, or non-existent (Gutberlet 2009; Gutberlet & Baeder 2008; Medina 2000; Sembiring & Nitivattananon, 2010; Wilson, Et al., 2006). The benefits that informal/cooperative recycling affords society and the environment go unrecognized and unacknowledged (Talyan, et al., 2008; Gutberlet, 2008). The contribution to the environment could be even greater if informal/cooperative recyclers received recognition and support for their work, and public awareness and participation were improved.

Unfortunately, waste management services are increasingly becoming privatized – that is, government reduces its activity or ownership within waste management services/industry while increasing the involvement of private large-

scale enterprises. The intention being to secure investment finance from private companies for solid waste equipment and facilities in return for contracts to provide service (Cointreau-Levine, 1994; van de Klundert & Lardinois 1995) – in many municipalities where the government will not, or cannot, deliver comprehensive and extensive MSWM services. Privatization of the recycling industry is the enclosure of recyclable resources commons, denying the informal/cooperative sector access to them, while granting contracts and access rights to private large-scale enterprises.

Such is the case in Sasolberg, South Africa (Samson, 2009), and in New Delhi, India (Wilson, et al., 2009). The livelihoods and citizenship of informal sector recyclers, who depend on the collection and sale of recyclables, are in jeopardy due to privatization of waste management services in New Delhi (Forsyth, 2005). These authors, as well as many others, advocate that the municipal authorities in low- and middle-income country cities preserve such crucial sources of employment for informal and cooperative recyclers through the formulation of a new model of inclusive waste management (Agarwal, et al., 2005: Barton, et al., 2008; Gutberlet, 2008; Memon, 2010; Wilson, et al., 2006).

Successful examples of such an inclusive model are evident in Brazil, where the encouragement and support for the organization of independent informal recyclers into cooperatives for the delivery of selective collection and recycling services in the cities including Diadema (Gutberlet, 2009), Belo Horizonte, Porto Alegre, Brasilia, São Sebastião (Dias & Alves, 2008); São Paulo (Grimberg, 2007), and many of the municipalities in the Metropolitan Region of São Paulo, including Ribeirão Pires (Gutberlet, 2012; FUNASA, 2010). The formation of cooperatives and networks of organized groups enables recyclers to achieve economies of scale, commercializing recyclables in bulk quantities for higher prices than they would otherwise receive for their product as independent recyclers.

2.3 Inclusive Integrated Solid Waste Management

Governmental support for an inclusive integrated solid waste management system

through policy, legislation, investment, and partnership, as well as civil support through participation in recyclables separation for selective collection, are crucial to improve the efficiency and sustainability of recycling schemes, recyclers' working conditions and occupational health, and overall quality of life (Baud, et al., 2001; Gutberlet & Baeder 2008; Sembiring & Nitivattananon, 2010). Involving the informal/cooperative sector into the municipal solid waste management system in such a way that guarantees the social autonomy of this sector, benefits all stakeholders in that the sharing of responsibility between public and private actors relieves some of the financial and administrative costs for municipal authorities in the provision of waste management services. Implementation of a selective collection scheme transfers the responsibility of separating recyclables from the waste stream onto the household, the source of generation; thus, this part of waste management costs are shifted from the public sector to the household sector (Nas & Jaffe, 2004). Informal sector recycling helps to further reduce municipal spending on the collection, transportation and disposal costs (Agarwal, et al., 2005; Schenck & Blaauw, 2011). Hayami, Dikshit & Mishra (2006) report that informal sector involvement in MSWM saves approximately US$ 4 million for the municipal authority in Delhi, India, while simultaneously improving municipal SWM services to residents.

Examples of successful integrated waste management systems operating in the various cities mentioned here show that their implementation and sustainability depend on what is often referred to as resource mobilization (Acioly, 2001; Taylor, 1999), a term describing the availability and the employment, or investment, of resources such as the five types of capital discussed in the next section of this chapter. Resource mobilization towards inclusive integrated solid waste management follows the recognition of the economic, social and environmental benefits of resource recovery and recycling activities, as well as the significant contribution of the informal/cooperative sector in these activities. This type of inclusive governance is built on a foundation of ecological and social justice politics. It supports participative management of resources and the social economy. It is

predicted on deliberative democracy and equitable partnerships among *all* waste management stakeholders including local authorities and other levels of government, civil society, and both formal and informal service providers (Charuvichaipong & Sajor, 2003; Forsyth, 2005; Gerometta, Häussermann & Longo, 2005; Gutberlet 2010; Kironde & Yhdego, 1997; van de Klundert & Lardinois, 1995; Taylor 1999)

To advocate for the integration of informal/cooperative sector recyclers into the formal MSWM system is not to imply that the informal sector ought to become formalized, or even that formalization would be desirable. The informal and formal sectors can work together – in fact, they already do. Manufacturers within the formal sector often purchase recyclable materials harvested and processed by the informal/cooperative sector. Furthermore, of primary importance to the informal sector recyclers is their social autonomy, the opportunity for which possibly may be curtailed or even denied through formalization. So, talking about the involvement of the informal sector and 'integrating' the informal sector is not to suggest that the cooperative must cease to operate as part of the social economy and instead take on a capitalist economic structure. It is simply to say that the informal and formal sectors can and should work together in partnership in the municipal solid waste management industry, and do so with mutual respect for the particular functions of each other.

Such a proactive approach has been demonstrated by Taylor's (1999) review of case studies on community-based MSW collection and recycling initiatives highlighting Manila, Philippines, and four Indonesian cities; Baud, et al.'s (2001) assessment of MSWM alliances between public, private, community-based and non-governmental organizations, and informal solid waste management actors in Lima, Peru; Chennai, India; and Manila, Philippines; and Gomes & Nobrega's (2005) study of door-to-door selective collection in the city of João Pessoa (Paraíba, Brazil), where the Recyclable Material Workers Association (ASTRAMARE) formed by a group of informal sector recyclers who collected from the open dump site in the city of João

Pessoa. ASTRAMARE has been receiving support from the city's Urban Cleaning Company (EMLUR12) since 2000. Other studies include Sembiring & Nitivattananon's (2010) study on the integration of the informal sector as privatization of part of solid waste management services in Bandung, Indonesia; FUNASA's (2010), Lino & Ismail's (2011), and Gutberlet's (2010, 2011, 2012) studies from the Metropolitan Region of São Paulo, which all focus on recycling cooperatives and selective collection initiatives supported by local, state and federal governments, as well as non-governmental and community-based organizations, and social movements.

In several Brazilian cities including Londrina and Diadema (Gutberlet, 2011a), and Belo Horizonte (Dias, 2008, 2011) the progressive approach to socially and environmentally successful implementation of integrated solid waste management has been through the organization of informal sector recyclers into legalized cooperatives, and the adoption of policy mechanisms that promote remuneration for the recyclers, and partnerships between the cooperatives and local government. In Belo Horizonte, Brazil, informal recyclers have been organizing into cooperatives and integrated with the formal solid waste management sector since the 1990s due to the social mobilization of recyclers, as well as governmental and NGO support. In 2008, Belo Horizonte's cooperatives collecting door-to-door recycled 52% of all recyclables collected in the city (Dias, 2011). This selective collection scheme has served as a model for other developing cities including Lima and Pune (Scheinberg, et al., 2010)

2.4 Cooperative Recycling: Capitals

The environmental service of recyclable resource recovery performed by the informal and cooperative recycling sector makes a significant contribution to municipal solid waste management, and as such, maintains and creates natural

capital [1]. Natural capital as the concept is defined by Rodrigues, Domingos, Conceição & Belbute (2005) and Roseta-Palma, Ferreira-Lopes & Sequeira (2010) an aggregate of all environmental assets including ecosystem functions, renewable and non-renewable natural resources. In this same vein, the present research considers recyclable resources as a form of natural capital that when utilized functions as environmentally sustainable waste management, natural resource and energy conservation. The greenhouse gas emission reduction resulting from the mobilization of the natural capital will be demonstrated in depth in the following section 3, *Waste Management, Recycling and Greenhouse Gas Emissions*. First, however, this section considered the findings of Sembiring & Nitivattananon's (2010) research of the informal solid waste management system in Bandung, Indonesia, in which the author proposes that social inclusion through the integration of this form of *natural* capital into a formal municipal solid waste management system, requires that four *other* capitals – namely *human, social, financial*, and *physical* capitals – be mobilized and built upon through partnerships between the informal and formal solid waste management sectors. These five capitals can be defined in the following ways:

- Natural: ecosystem functions, renewable and non-renewable natural resources, and recyclable resources.
- Human: individual skills, abilities, training, or education and the experience and skills from routine work.
- Social: norms, values, trust and reciprocity, rules, and networks.
- Financial: financial assets available for investment (microcredit, funding schemes for recycling projects, etc.)
- Physical: property, land, buildings, machines, and public infrastructure such as schools, hospitals, roads, and drains.

(Sembiring & Nitivattananon, 2010).

[1] It is understood that the use of the term *capital* here is at risk of being misconstrued as intentionally framing the environment, the social economy and its actors in terms of the hegemonic capitalist economic system. However, this is not the spirit in which the present research uses the term *capital,* but instead uses it in the sense of *asset.*

According to Roseta-Palma, et al. (2010) social capital refers to trust, social norms, and social networking. Gutberlet's (2009) research, as well as the numerous and diverse studies cited above in TABLE 1, strongly suggest that a waste management system steered by triple-bottom line policies must be socially inclusive. This body of research shows that when networks and social relations are based on personal and social autonomy and the decentralization of power and responsibility to its members of the network, they create a space for democratic deliberation, trust building, reciprocity and social cohesion. In other words, they build and reinforce the social capital that is fundamental to successful collaborative work schemes such as the involvement of informal recyclers in the delivery of municipal solid waste management services. The organization of informal recyclers into cooperatives and partnerships with municipal agencies can result in a more democratic decision-making and participative management of resources; community-based development; job creation; more secure employment; poverty alleviation; individual and group capacity building; personal and professional development; and improved occupational health conditions (Baud, et al., 2001; Forsyth 2005; Gonzenbach & Coad, 2007; Gutberlet 2008, 2009, 2010, 2012; Medina, 2005; Tremblay & Gutberlet, 2010). Informal/cooperative recycling also generates technical knowledge of the recycling process (Uiterkamp, et al., 2011). All the above values and benefits facilitate and the creation and reinforcement of human capital, which is an essential criterion of sustainability (Brundtland, 1987; Troschinetz & Mihelcic, 2009). Social and human capitals, in turn, have virtuous positive feedback into financial and natural capitals.

Social capital is also developed through the direct contact that door-to-door collectors often have with residents, positioning recyclers well for opportunities to raise awareness among residents about the importance of source-separation and selective collection of recyclables. Greater awareness among the public reinforces the functions of recycling as natural capital, and tends to improve participation in the separation of recyclables from the waste stream at the household level (Troschinetz & Mihelcic 2009; Morrissey & Browne, 2004; O'Connell, 2011), and

thus, increases the recyclers' yield of recyclable resources through selective collection, and generates financial capital for the recyclers through higher sales. In addition, providing a steady flow of recyclable resources to the recycling industry contributes to the economic development of the city (Fehr & Santos, 2009).

Involving the informal/cooperative sectors in municipal solid was management offers the potential to strengthen social economy, an action towards re-embedding the market within society (Wall, 2005). This merging of the economic and social spheres is innovative, generating new industry and employment in alignment with social values such as equity, mutual and cooperative exchange (Gerometta, et al., 2005; Gutberlet, 2010), creating additional opportunities to generate financial capital. Such gains in financial capital can be fed back into the development of all other capitals – physical, social, human, and natural.

Supportive policies and legislation that address the needs of socially excluded and impoverished people, safeguarding the employment opportunities available in the informal and cooperative recycling activities. Encouragement and support for the formation of cooperatives, preferential awarding of contracts for selective collection programs to this sector, and investment of financial, physical, and public infrastructure capitals can have virtuous positive feedback for social and human, financial and natural capital, including:

- Social and human development; dignity, self-esteem, and empowerment (social and human capitals);
- Economic growth and the development of the reverse logistics and recycling (resource recovery and remanufacturing) industries (financial, social, and human capitals); and
- Realization of climate change mitigation and waste management targets (natural capital, discussed in the following section).

2.5 Recycling: Generating Natural Capital

Recycling is commonly regarded as the most significant waste management activity to mitigate the impacts and costs of waste generation and management, performing

better than landfilling and incineration (Morris, 1996, 2005; Skovgaard, Hedal & Villanueva, 2008). There are a multitude of studies highlighting the benefits of recycling including diversion of resources from landfill disposal, conserving the capacities and lifespans of existing landfills (Chester, Martin & Sathaye, 2008; Gurung & Polprasert, 2007; Moreno-Sánchez & Maldonado, 2006) and the reduction of disposal costs (Fehr & Santos, 2009; Cointreau-Levine, 1994); greater resource efficiency, natural resource and energy conservation (Mendes, Amaraki & Hanaki, 2004; Moreno-Sánchez & Maldonado, 2006; Morris, 1996, 2005; Schmidt, Holm & Merrild, 2007) and the avoidance of greenhouse gas emissions, particularly methane (CH_4) and carbon dioxide (CO_2) (Björklund and Finnveden, 2005; Calabrò, 2009; Chester, et al., 2008; Diaz & Warith, 2006; Donovan, et al, 2011; Eriksson, et al., 2005; Morris, 2005; Pimenteira, et al. 2004; Skovgaard, et al., 2008). The avoidance of greenhouse gas emissions is primarily because recycling is an energy efficiency measure involving changes in the production process (Martinsen, 2001), namely the replacement of virgin resources with recycled resources, as illustrated in FIGURES 3 and 4, thereby lowering the energy consumption during production.

3. Waste Management, Recycling and Greenhouse Gas Emissions

The principal climate-relevant greenhouse gases generated through solid waste management activities are methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) (Calabrò, 2009; Machado, Carvalho, Gourc, Vilar & Nascimento, 2009, Gentil, Aoustin & Christensen, 2009; Sandulescu, 2004). Downstream CH_4 emission is associated with landfill disposal of biodegradable resources and is the most climate-relevant of all waste-related greenhouse gas emissions. It has the greatest global warming potential (GWP), 21 times that of CO_2, and makes up 55% of all landfill-related greenhouse gas emissions; CO_2 accounts for 44%, and N_2O counts for less that 1% (Intergovernmental Panel on Climate Change, 2007; Koneczny & Pennington, 2007). Waste management-related CO_2 and N_2O emissions are due to incineration, especially of plastics. Aerobic composting and anaerobic digestion result in negligible CH_4 emission, but this is mitigated through avoidance of landfill disposal of biodegradable waste, and thus, avoidance of a larger emission of CH_4

resulting in an overall reduction of greenhouse gas emissions (Donovan, et al., 2011; ICF Consulting 2005). As mentioned earlier, recycling also results in an overall reduction of greenhouse gas emission, which is described in the following section.

3.1 Recycling: Energy Conservation and Greenhouse Gas Emissions Reductions

Greenhouse gases (commonly expressed in related literature as an aggregate of gases, referred to as CO_2 equivalents [CO_2-eq.]), are either emitted or avoided in the upstream and downstream stages in the life cycle of municipal solid waste management system (US EPA 2006), as follows:

Upstream

- Upstream emissions: virgin raw materials acquisition and manufacturing; higher fossil fuel energy consumption for virgin resource extraction and use in manufacturing in the absence of recycling.
- Upstream emission avoidance: recycling leads to significant upstream avoidance through virgin resources displacement, where recycled resources replace virgin resources in the fabrication of metal, glass, plastic and paper products. Reducing the need for virgin resource extraction improves energy efficiency and resource efficiency (Bogner, et al., 2008; Chester, et al., 2008; Diaz & Warith, 2006; Finnveden, et al., 2005; Holmgren, 2004; Liamsanguan & Gheewala, 2008; Mohareb, Warith & Diaz, 2008; Morris, 2005; Pimenteira, et al., 2004; Skovgaard, et al., 2008). Other upstream impacts occur through landfill gas (CH_4) collection and forest carbon sequestration (Thorneloe, Weitz, Nishtala, Yarkosky & Zannes, 2002; US EPA, 2006).

Downstream

- Downstream emissions: the diverse waste management activities (recycling, composting, incineration, and landfilling) generate variable amounts of emissions. For example, fossil CO_2 emissions are associated directly with the recycling operations as energy and some virgin resources are consumed during collection and transport of materials, processing, and remanufacturing (ICF Consulting, 2005).

- Downstream emission avoidance: with recycling, both CH_4 and CO_2 emissions are avoided through the diversion of resources from landfills, through the resource recovery and recycling of paper/cardboards and other biodegradable material (Donovan, et al., 2011; Morris, 2005; US EPA, 2006), and through source reduction - waste minimization at the point of waste generation – minimizing the load of material that must be landfilled.

Below, TABLE 3 shows just a few of many examples of the energy conservation and greenhouse gas emission reductions through the use of recycled materials.

3.2 Greenhouse Gas Accounting for Waste Management: Life Cycle Assessment versus the Clean Development Mechanism Method

A handful of methods for assessing the greenhouse gas emissions from solid waste management activities are available. Since the early 1980s (Andrews, 2002), much of the research into the environmental impacts, including greenhouse gas emissions, from waste management activities has been based on the life cycle assessment (LCA) method.

The LCA approach is a widely used, internationally standardized application for environmental management (ISO 14040:2006; International Organization for Standardization, 2011). The method assesses the direct and indirect natural resource use and pollutant emissions and the environmental impacts that occur 'upstream' and 'downstream' of the manufacturing, use and disposal of a product (e.g., packaging) or a service (e.g., selective collection; recycling), throughout its life cycle or product system. The whole life cycle encompasses extraction of virgin resources; energy acquisition and consumption; manufacturing; and product consumption, reuse, recycling, and ultimately, disposal (Ayers & Ayers, 2002; Baumann & Tillman, 2004). A full-scale LCA involves the inventory of all environmentally relevant material and energy flows within the boundaries of the product system.

TABLE 3. Studies using Life Cycle Assessment (LCA), Greenhouse gas (GHG) Accounting, and WARM Methods to Estimate GHG Emission Reductions and Energy Conservation from Recycling

Study	**Method**	**GHG reduction t CO2-eq. per tonne recycled**		**Energy conservation MWh (%) per tonne recycled**
Chaturvedi, 2009; India Informal recycling	US EPA WARM online GHG calculator	Paper Plastics Metals Glass	1.06 0.42 1.44 0.09	
Energy and Environmental Research (*Institut für Energie- und Umweltforschung*; IFEU), 2009; Europe** Recycling, general	IFEU SWM-GHG calculator	Plastics Steel Aluminum	0.414 2.025 11.1	
Damgaard, Larsen & Christensen, 2009; Europe Recycling, general	GHG accounting	Aluminum Steel	5.0 - 19.3 0.6 - 2.4	
Merrild, Damgaard & Christensen, 2009; Europe Recycling, general	GHG accounting	Paper	-1.5 – 4.4	

TABLE 3 (Continued). Studies using Life Cycle Assessment (LCA), Greenhouse gas (GHG) Accounting, and WARM Methods to Estimate GHG Emission Reductions and Energy Conservation from Recycling

Pimenteira, et al., 2004; Brazil Recycling potential: 1% - 100% recycling rate	GHG and energy accounting	Aggregate of dry recyclables	0.014 - 11.5	steel paper aluminum plastics glass	5.06 (74.97) 3.5 (70.48) 16.9 (96.00) 5.3 (78.63) 0.64 (13.25)
Morris, 2005; USA Formal curbside recycling	LCA	Aggregate of dry recyclables	2.27		
		Biogas	0.012		
Mohareb, et al., 2008; Canada Formal curbside recycling	LCA	Aggregate of dry recyclables	1.037		
Rigamonti, et al., 2009; Italy Formal curbside recycling	LCA	Steel Paper Aluminum Plastics Glass	0.405 0.557 9.855 1.12 0.722	steel paper aluminum plastics	2.47 (81.2) 1.7 (99.4) 6.1 (93.5) 8.17 (91.4)

A full-scale LCA approach is not necessary when only one environmental impact such as greenhouse gas emissions (often expressed as CO_2-eq. or GWP) is being assessed. When this is the case, a simplified LCA method (such as IFEU's (2009) *Solid Waste Management – Greenhouse Gas (SWM-GHG) Calculator*) or a greenhouse gas accounting method (such as the United Nations Framework Convention on Climate Change's Clean Development Mechanism methodologies) is more pragmatic, particularly for low- and middle-income countries where the data necessary for a full LCA study are unlikely to be readily available (Barton, et al., 2008).

IFEU's (2009) *Solid Waste Management – Greenhouse Gas (SWM-GHG) Calculator*) simplified LCA is even overly broad in scope for the purpose of this present research, as the SWM-GHG assesses the greenhouse gas emissions of the municipal solid waste flow through a municipal solid waste management system, comparing various treatment options. The purpose here is to measure the greenhouse gas emission reductions achieved through one waste treatment method (i.e., recycling) of a select portion (plastics, paper/cardboard, metals, and glass) of the municipal solid waste stream. Given this focus, and in consideration of the opportunity available for informal/cooperative recycling sector participation in the carbon market, the most appropriate method for measuring the greenhouse gas emission reductions of recycling is through the United Nations Framework Convention on Climate Change's (UNFCCC) Clean Development Mechanism (CDM) [2]greenhouse gas accounting methodology, labeled *AMS III-AJ: Recovery and Resource recovery and recycling of Material from Solid Waste*, and the *Tool to determine methane emissions avoided from disposal of wastes at a waste disposal site.* (UNFCCC, 2008, 2010, 2011a, b, c).

[2] The Clean Development Mechanism is defined and discussed indepth on pages 32-35.

bottom line' sustainability because they do not consider social aspects of waste management (Morrissey & Browne, 2004), or the socio-economic advantages of recycling (Baumann & Tillman, 2004). To surmount this shortcoming, a mixed methods approach is necessary, using qualitative methods including participant observation, interviews and questionnaires.

Another drawback cannot be so easily addressed, however, and that is the uncertainty of results due to data quality, especially with respect to 1) waste processing and disposal options, 2) waste composition, and 3) the lack of temporal and spatial considerations (Hanandeh & El-Zein, 2010). This uncertainty of results is clearly illustrated by the discrepancies in the results of the various studies displayed in TABLE 3. Due to this uncertainty, scientific debates exist regarding the greenhouse gas accounting of paper waste management, for example. There is the argument that landfilling paper is preferable to recycling because paper is a slow decomposer, and therefore, contribute very little to the overall CH_4 emissions – the landfilled paper acts as a carbon sink (Bogner, et al., 2008; Merrild, et al., 2009). In direct contrast, Schmidt, et al., (2007) shows that resource recovery and recycling of paper has an *overall negative* global warming potential, meaning it reduces more emissions than it produces, making it the preferable option over both landfills and incineration, in respect to climate change mitigation. Furthermore, it is argued that paper/cardboard occupies a huge amount of space and has a high energy content, so in terms of the lifespan of the landfill and the energy consumed in paper manufacturing, recycling is the preferable option over landfilling or waste-to-energy incineration (Morris, 2005, see TABLE 3). For example, the avoidance of paper/cardboard disposal in all UK landfills currently reduces CH_4 emissions of these landfills by 52.1% (Donovan, et al., 2011).

There is also debate in the literature about the importance of transportation in the greenhouse gas accounting of waste management. On one side of the debate, authors such as Eisted, Larsen & Christensen (2009), and Clift, et al. (2000) suggest that it is important to consider transportation in the LCA of recycling, as the

collection, transfer and transport of recyclables contribute to emissions of greenhouse gases. The transport of solid wastes can account for a significant portion of the overall environmental impact, as well as the economic cost. On the other side of the debate, Hanandeh & El_Zein (2010) contend that transportation has the least impact, while specific waste processing and disposal processes have the greater impact than composition on LCA results. Hanandeh & El_Zein's conclusions are also in direct contrast to Chester, Martin & Sathaye (2008), who argue the specific operations of resource recovery and recycling are less critical than the type and quantity of material that is actually recycled, and therefore waste management policies should put emphasis on increasing recyclable yield. According to Pisoni, Raccanelli, Dotelli et al. (2009), minimizing travel distances is necessary to minimize transport-related emissions of greenhouse gases; however, it is important to maximize source separation and recycling.

3.3. Waste Management, Climate Change Mitigation, and the Clean Development Mechanism

Contributors to the fourth assessment report of the Intergovernmental Panel on Climate Change, Forster, Ramaswamy, Artaxo, Berntsen, Betts, Fahey et al. (2007), place waste and its management as one among seven key contributors to climate change. For example, the waste sector accounted for approximately 18% of global anthropogenic CH_4 emissions in 2004 (Bogner, et al., 2008). Concern about climate change and about the greenhouse gas emissions generated by solid waste and its management, demand that waste management policy and climate change mitigation initiatives be considered synergistically (US EPA, 2006). To this end, landfill gas projects were among the first Clean Development Mechanism (CDM) projects registered by the United Nations Framework Convention on Climate Change (UNFCCC, 2012).

The CDM is a carbon finance mechanism, i.e., a vehicle through which municipal governments in low- and middle-income countries can integrate environmental policies and initiatives with social and economic goals, and catalyze

sector investment (Barton, et al., 2008; Oliveira, 2009; The World Bank, 2009). It is one of the three market-based mechanisms (besides Emissions Trading and Joint Implementation, which will not be discussed here) supporting the Kyoto Protocol, an international agreement linked to the UNFCCC under which developed countries have committed to targeted greenhouse gas emission reductions. The CDM is designed to hold high-income countries (termed *Annex 1 parties*) under the Kyoto Protocol) responsible for limiting or reducing their greenhouse gas emissions, help countries meet their emissions reduction targets, and encourage the private sector and low- and middle-income countries to contribute to emission reduction efforts. Further, it was designed with the intention of assisting such countries achieve greenhouse gas emissions mitigation through sustainable development (Barton, et al., 2008; Gurung & Polprasert, 2007; UNFCCC, 2012).

The CDM should enable low- and middle-income nations to participate in the treaty by selling carbon credits (termed 'certified emissions reductions' [CERs] and measured in tons of CO2-equivalent) to high-income countries with emissions commitments, the intention being to create sustainable development benefits and cost-effective reduction of greenhouse gases for low- and middle-income nations (UNFCCC, 2012; Boyd, 2009; Olsen, 2007). The CDM is part of the emerging carbon market that can play a major role in financing mitigation projects (Clapp, Leseur, Sarotr, Briner & Corfee-Morlot, 2010).

3.3.1 Carbon Emissions Reductions

Certified Emission Reductions (CERs) are carbon credits issued by the CDM Executive Board for emission reductions achieved by CDM projects and verified by a Designated Operational Entity (DOE) under the rules of the Kyoto Protocol. CERs can be held by public (governmental) and private corporations on electronic accounts with the United Nations, can be purchased directly from parties responsible for causing the reduction, and they can be resold in the carbon finance marketplace. CERs can be used by developed countries that are party to the Kyoto Protocol, or by operators of installations covered by the European Union Emission

Trading Scheme (EU ETS), the first large emissions trading scheme in the world, to comply with their greenhouse gas emission limitation and reduction targets (European Commission Climate Action, 2010).

In Brazil, a CDM project must complete a seven-step cycle. These seven steps include:

1) Preparation of project design document (PDD), using baseline and monitoring methodologies that have been approved by the CDM Executive Board. A baseline methodology is the means to estimate the emissions that would have been created in the business-as-usual (baseline) scenario – e.g., landfill disposal – in the absence of project activity (e.g., recycling). A monitoring methodology is the means to calculate the actual emission reductions from the project. CERs are calculated by subtracting the project emissions from the baseline emissions.
2) Validation by the DOE of project compliance with the regulations of the Kyoto Protocol;
3) Approval by the Designated National Authority (DNA), the Interministerial Commission on Global Climate Change. The DNA is composed of representatives from 11 federal Ministries chaired by the Minister of Science and Technology, and vice-chaired by the Minister of Environment and is responsible for approving and facilitating participation in CDM projects, verifying the project's contribution to sustainable development;
4) Submission to the Executive Board for registration;
5) Monitoring;
6) Verification / certification; and
7) Issuance of units under the project agreement.

(Ministry of Science, Technology and Innovation [*Ministério da Ciência,* Tecnologia e Inovação; MCTI], 2008a)

The DOE is the private certifier, a domestic legal entity or an international organization accredited and designated by the CDM Executive Board to validate projects and verify emission reductions. The DOE validates and subsequently

requests registration of a proposed CDM project activity from the Designated National Authority (DNA), the body that approves projects and facilitates participation. It is then the responsibility of the DOE to verify and certify emission reductions of a registered CDM project activity, and request the CDM Executive Board to issue certified emission reductions (CERs) to the project. Each CER credit is equivalent to one tonne of CO_2/CO_2-eq.

The 'Methodologies Panel' and 'Small-scale Working Group', the 'Registration and Issuance Team', and the UNFCCC Sectretariat all support the CDM Executive Board, and so can have a major influence on improving the CDM's sustainability record through advocacy and support for informal /cooperative sector recycling projects (UNFCCC, 2012)

3.4 Waste Management, Climate Change Policy and the CDM in Brazil

Brazil is one of the leading countries in terms of its number of approved CDM projects, and it has been successful in creating a carbon market. In terms of number of CERs issued, Brazil currently ranks 4th (after China, India and South Korea) among countries participating in the CDM (Hultman, Pulver, Guimarães, Deshmukh, & Kane, 2010). One of the region's most significant climate change related initiatives is in the area of waste management. Heretofore, however, waste-related CDM projects have so far only focused on large-scale private sector landfill gas projects such as methane capture-and-flare (destruction) and methane-to-energy (thermal/electrical energy generation) (Rogger, et al., 2011; UNFCCC 2010). In their study comparing different emission reduction options in the solid waste management sector of low- and middle-income countries, Barton, et al. (2008) found that considerable reductions in greenhouse gas emissions are achieved through landfill gas projects. Their profitability in CERs makes them a favourite for investors (Fenhann & Staun, 2010).

As of 2009, one of the main federal government programs in the waste management sector is the *Projeto CDM Aplicado à Redução de Emissões de Gases Gerados nas Áreas de Disposição Final de Resíduos Sólidos* (Applied CDM Project to

Reduce Emissions of Gases Generated in Areas of Disposal of Solid Waste). Funded by The World Bank and the Government of Japan, the project is administered by the *Ministério das Cidades – Secretaria Nacional de Saneamento Ambiental* (Ministry of Cities - National Bureau of Environmental Sanitation), the *Ministério do Meio Ambiente* (Ministry of Environment), and The World Bank. The use of biogas from landfills for power generation is one of the foci of this project, with the purpose of facilitating sustainable development in urban areas of 200 of the most populous municipalities in the country. The justification for this project is the concept of the CDM as an effective tool for the implementation of economic social and environmental programs. The socio-economic and socio-environmental dimensions of this project are its intended contribution to social inclusion and empowerment of people relying on resource recovery and recycling as a livelihood (Corporation of Environmental Sanitation Technology [*Companhia de Tecnologia de Saneamento Ambiental*; CETESB], 2010).

3.4.1 São Paulo State Policy on Climate Change

São Paulo's State government has shown commitment to climate change within its State Policy on Climate Change – ACT Nº 13.798 – created in 2009. Some of the main objectives of this policy include:

> "1. To ensure the *compatibility of socio-economical development with the protection of the climate system*;
> "2. To foster projects for the reduction of emissions, sequester or sinks of greenhouse gases, including those of the … *CDM*;
> "3. To establish ways for a productive transition that generate *behavior changes*, in the sense of stimulating a *positive environmental change in the patterns of consumption*, in economical activities… and in the use of urban … land, focused on the reduction of the emission of greenhouse gases and in the increase of absorption by sinks"…

> "8. To stimulate *participation of the various segments of São Paulo's society in the integrated and shared management* of the instruments of this law;
> "9. To define and effectively *apply indicators and targets on environmental performance in the productive areas of São Paulo's economy*;
> "10. To *impart value to the environmental assets* and to reduce the State's environmental liabilities"
> (Estado de São Paulo, 2009, 1).

These objectives align well with the CDM sustainable development objectives for Brazil, as laid out by the country's DNA, the Interministerial Commission on Global Climate Change. The registration of a proposed CDM project activity can only take place once the DNA has confirmed that the project activity assists it in achieving sustainable development of the country, according to five basic criteria:

- income distribution,
- local environmental sustainability,
- development of working conditions and net generation of employment, training and technological development,
- regional integration, and
- linkages with other sectors.

(MCTI, 2008b)

There are now thirty-three approved CDM landfill-gas projects in Brazil. Fourteen of these projects are in the State of São Paulo, and three of them situated are in the Metropolitan Region of São Paulo (MCTI, 2008c). Since 2005, the municipality of São Paulo has installed two of the State's largest landfill (methane) gas-to-energy CDM projects: Bandeirantes landfill and São João landfill in the city of São Paulo. These Landfill gas-to-energy plants capture and burn methane (CH_4) produced by decaying waste and are expected to prevent nearly 13.3 million tons of CO_2-eq. from entering the atmosphere by 2012 (CDM Executive Board, 2005, 2010).

An inventory of its emissions show that methane from landfills contributed 23.5% of the city's total emissions (Oliveira, 2009).

The third project is the Lara landfill in the city of Mauá (planned shutdown of the landfill site in 2014). The project activity consists of the installation, operation and maintenance of a comprehensive system of capture and combustion of landfill gas and the installation of gas and power generator-engines at Lara's existing landfill. The cost of the project is approximately R$ 14 million, plus operating costs and maintenance of the necessary equipment installations (Det Norske Veritas, 2004). The CDM provides funding to the project through sale of Certificates of Emission Reductions (CERs) to public or private foreign buyers who have committed to the reduction of greenhoue gas emissions.

The greatest benefit of the Lara landfill project is the reduction of approximately 500,000 tonnes of CH_4 emissions (10.5 million tonnes CO_2-eq.) throughout the project life, compared with the current situation. Also proposed is the simultaneous introduction of improved waste management practices including social programs designed by Lara and Trade Co-Generation Power Ltd. (abbreviated "Lara Energia") aimed at improving the life situation of local stakeholders (Det Norske Veritas, 2004). Oliveira (2009) notes that through the sale by international auction of CERs earned by the Bandeirantes and São João plants, millions of dollars are available for investment into social projects in the communities surrounding the landfill.

3.4.2 CDM Critiques

The previous example of Lara landfill notwithstanding, the trend has been that social values and civil society have in the past been under-represented in so-called 'sustainable development' mechanisms, putting priority on economic before social objectives. The CDM has not escaped criticism on this point. Uncertainty exists regarding the efficiency of past and ongoing CDM projects to deliver on any real

substantial social development-related sustainable development benefits (CDM Watch, 2012; Olsen, 2007). One criticism is that the CDM tends to favour large-scale projects in forestry and waste-to-energy plants that do not assist in mitigating global climate change policy and offer little immediate developmental benefit for the majority of the people in host countries (Forsyth, 2005). This is the case in Brazil, where there exists 33 CDM landfill gas-to-energy projects. Informal/cooperative recyclers decry the proliferation of such projects because they squander valuable resources, burying them when they should be recycled, generating work and income, particularly for the disadvantaged proportion of the population (Gutberlet 2011, 2012; SWACH, 2012). Furthermore, landfill gas-to-energy projects do nothing to discourage the landfilling of waste.

The importance of employment and the quantity and quality of jobs in sustainable development is often ignored in sustainability assessments of CDM projects (Rogger, et al., 2011). For instance, the landfill gas-to-energy project at the Lara landfill in Mauá, São Paulo, created only 6 – 10 long-term jobs (Det Norske Veritas, 2005) versus an average of 36 recycling positions per cooperative (FUNASA, 2010). Decision makers have tended to prefer integrating the end-of-pipe abatement technologies rather than informal sector involvement (Sembiring & Nitivattananon, 2010), even though the cost for the generation of one job in the cooperative recycling sector is smaller than in any other sector (Dias & Alves, 2008), at approximate R$ 3000.00 – 5000.00 per position (MNCR, 2006) versus a minimum of R$ 17,000.00 in the formal sector (FUNASA, 2010).

Hopefully, CDM projects focused on resource recovery and recycling will now manifest as the UNFCCC has made available a methodology that accounts for greenhouse gas emissions reductions through resource recovery and recycling, inclusive for the informal/cooperative sector. Chaturvedi (2009), director of Chintan Environmental Research and Action Group, which made its assessment of greenhouse gas emissions reduction through informal resource recovery and recycling in India by employing the material specific emissions factors developed for the US EPA Waste Reduction Model (WARM), noted this lack of inclusivity in the

CDM methodology. Chaturvedi saliently pointed out, "the structural inadequacies of the CDM are creating climate injustice by forcing the institutional sidetracking of [informal recyclers]" (2009, 5). This shortcoming could be addressed by synchronizing the incorporation of a social development agenda within both CDM and solid waste management policy frameworks, and by the synchronization of these policies such that climate change mitigation strategies developed for the waste management sector can have the additional benefits of enhanced economic and social development (Reddy & Assenza, 2009; Rogger, et al., 2011).

For CDM projects to achieve the so-called ''triple-bottom-line" of sustainability (Barton, et al. 2008), there must be achieved a consensus of three different interests, namely economic, social and natural (Najam, et al., 2003). The CDM program must better align and synchronize itself with the Millennium Development Goals (IPEA, 2004; UN, 2011), the local government, civil society, and local social and economic development goals. São Paulo's state government is demonstrating its intention to realize such synchronization with its state action plan for the mitigation and adaption to climate change. Improving municipal solid waste management is one of the proposed actions, which aims to improve partnerships with recycling cooperatives and increasing the rate of recycling (São Paulo 2011).

4. Methods

4.1 Theoretical Background

The current research is mainly situated within literatures on urban sustainability, sustainable waste management, resource management, climate policy, industrial ecologies, international social development and environmental health. Within this broader scholarship, waste-related greenhouse gas accounting and the development of economically, environmentally, and socially sustainable solid waste management systems are identified as key focus areas for public health, environmental policy and sustainable development.

Society and the economy can evolve towards more ecologically (and socially) sustainable industry through a well-developed and integrated recycling sector (of which resource recovery and reverse logistics are a part). This evolution can be seen as nothing less than a "reorganization of the material flow through the urban system… the 'backloop' of the adaptive cycle of growth, collapse, reorganization, renewal and re-establishment, to use the words of C. S. Holling (2003). Actually, what we are talking about here is a shift – a reparation – of the human-environment relationship, that is, of human interaction with the material world. This evolution of society and the economy towards a sane relationship and interaction with the environment is what I mean when I refer here to 'sustainability', which Berkes, Colding and Folke (2003) describes as a "dynamic process that requires adaptive capacity for societies to deal with change" (2). Climate change and the growing problem of waste generation and management both demand that society adapts – which should involve a re-organization of economies to avoid the generation of waste, in the first place, and barring that, to stimulate the growth of the recycling industry – as part of a larger transformation towards a less material- and energy-intensive economy and way of life.

The theoretical background of this research draws from systems theory, which "argues that the understanding of the essential properties of the parts of a system comes from an understanding of not only these components but of their interrelations as well. Understanding comes from the examination of how the parts operate together, and not from the examination of the parts themselves in isolation" (Berkes, Colding & Foke, 2003:5). Which means that to look at waste management, and resource recovery and recycling specifically, without considering its multiple social, economic, political and environmental interrelations is to misunderstand the "the essential properties of the parts of a system," and by extension, the system itself. Which is why the current research examined the resource recovery and recycling activities of a recycling cooperative through both a quantitative, greenhouse gas accounting method, and qualitative methods including participant

observation, interviews and questionnaires, gaining insight into its environmental *and* the socio-economic aspects.

In the forward to Berkes, Colding and Folke's *Navigation Social-Ecological Systems* (2003), C.S. Holling writes: "The increase in vulnerability comes from increase in structure that adds complexity but also vulnerability" (XV). We could insert the phrase "of the urban system" into this passage and it would still read true. The complexity of the urban system – the axis around and through which people, labour, energy, technology, and materials flow, and where social, economic, and ecological systems are densely woven – lends to vulnerability against exogenous and endogenous forces, including the geopolitical and cultural effects of a global economy, and the social, economic and environmental impacts of the metabolism of so much material and energy.

Actor-network theory explains the role of recycling cooperatives in sustainable waste management, climate change mitigation, and social inclusion in São Paulo, Brazil. Actor-network theory provides the epistemological basis for the research, as it studies a heterogeneous space of multiple actors (people, materials, information) and networks that perpetuate the structures, mechanisms, and events of informal and cooperative sector recycling. Bosco (2006: 136) writes, "ANT [actor-network theory] is about uncovering and tracing the many connections and relations among a variety of actors (human, non-human, material, discursive) that allow particular actors, events and processes to become what they are". In the context of cooperative recycling, the focus of actor-network theory is on the pathways and connections between actors involved in a recycling cooperative, the reverse logistics chain, the production and consumption of commodities, the municipal government, the urban environment, public policy, waste management policy, greenhouse gas emissions, and so on. The multiple connection between various actors across the recycling actor network are what makes resource recovery and recycling viable strategies in achieving 'triple bottom line' sustainability of solid waste management, climate change mitigation, and poverty alleviation.

Actor-network theory draws attention to the importance of the links, and the traffic through these links, in networks of association (Seuring, 2004; Thrift, 2000); it is a systems perspective compatible with the objective of life-cycle assessment. It also provides a broader context in which to situate recycling and recyclable materials. Part of this explanation will be provided through a greenhouse gas accounting of cooperative recycling. Through actor-network theory, the devaluation of waste/valorization of recyclable resources can be visualized as a relational effect of industry, producers and consumers, the urban environment and its residents, domestic/public spaces and material goods, nature and resources, culture and values, landfills and policy.

4.2 Objectives and Rationale

The primary objective of the research was to assess the flow and processing of recyclable resources including paper/cardboard, glass, metals and plastics through the recovery and recycling activities as performed by the Cooperpires recycling cooperative, located in Ribeirão Pires, São Paulo, Brazil. This assessment informed the greenhouse gas accounting method using the CDM methodology AMS III-AJ: Recovery and Recycling of Material from Solid Waste supplemented by the Methodological tool to determine methane emissions avoided from disposal of wastes at a waste disposal site.

The secondary objectives of the research were: 1) to gain qualitative insight into the efficiency of *Cooperpires*' recovery and recycling activities, the challenges that *Cooperpires'* members face in their daily operations, their role as environmental service provider, and their remuneration for this service, and 2) to explore the opportunity for Cooperpires to engage in the carbon credit market.

The primary and secondary objectives were achieved through a case study conducted with the *Cooperpires* recycling cooperative. *Cooperpires* was chosen as

the subject of the study because it is one of the 11 cooperatives participating in the Participatory Sustainable Waste Management (PSWM) project (an initiative of Dr. J. Gutberlet of the CBR lab, UVic Geography), of which the current research is an ancillary project. The request for this study, with its particular objectives, came from within the recycling community. Together, the PSWM management committee and recycling cooperative leaders determined that Cooperpires was sufficiently organized to accommodate research activities at their facility, participate in the research, and provide additional, secondary data material flow for January – December, 2010.

This study's objectives provided the means to answer the following questions:

1. What contribution does cooperative sector recycling make towards greenhouse gas emission reductions and climate change mitigation?
2. What contribution does cooperative sector recycling make towards the formal, integrated municipal solid waste management system in a municipality of São Paulo, Brazil?
3. How does cooperative sector recycling contribute towards social inclusion and poverty alleviation?

4.3 Study Area

The research is situated in the subtropical city of Ribeirão Pires – geographic coordinates 23°42′55″S 46°25′10″W – one of the 39 municipalities in the Metropolitan Region of São Paulo, and one of 645 municipalities in São Paulo state. Ribeirão Pires, shown in FIGURE 2, borders the cities of Mauá and Rio Grande da Serra, covering an area of 107 km^2. The municipality has a population of 112,011 inhabitants, with a population density of approximately 1,047 hab./km^2, an annual population increase of 2%. The life expectancy is 69.93 years; the metropolitan Human Development Index is 0.807 and the literacy rate is 95% (the Human Development Index and literacy rate for the Metropolitan Region of São Paulo are

0.828 and 92.6%, respectively; FUNASA, 2010); and the per capita income is R$ 900.00/month (CA$ 517.83). The municipal GDP in 2009 was R$ 680 million, and a municipal budget of R$ 124.3 million (Secretaria Municipal de Saúde e Higiene, 2010). In 2009, the municipality received R$ 277,000 of federal funding towards the management of its municipal solid waste. This funding was funnel into its recycling program and the construction of the triage facility (SNIS, 2011).

4.4 Data collection

Most of the research activities took place at multiple locations around Ribeirão Pires, including the city centre, surrounding neighbourhoods, and the *Cooperpires* triage facility outside the city. Primary and secondary data was collected through both quantitative and qualitative methods. Ethics approval – protocol number: 10-340 – for participant observation, interviews, and the questionnaire was obtained Sept. 2010. In Sept. 2011, ethics approval was extended until April 2012. Consent by cooperative members to participation in the research activities was given in writing and audio-recorded. Consent forms accompanied the questionnaires sent to the reverse logistics companies.

Primary data

Primary qualitative data collection was carried out by a mixed methods approach and included participant observation, structured interviews, and questionnaires. The interview guide is given in APPENDIX 1, and the questionnaire is given in APPENDIX 2. Participant observation and interview methods surveyed the structural efficiency, organization, and resources of the cooperative, namely the social, human, financial, physical, and natural capitals inherent in, and created through, cooperative recycling. This data supplements the results of the greenhouse gas accounting method, which does not take into consideration economic and social

aspects of recycling. The primary qualitative data goes some way towards filling these knowledge gaps in terms of assessing 'triple bottom line' sustainability.

(Source: Gutberet, 2012)

FIGURE 2: Study area. Ribeirão Pires within the Metropolitan Region of São Paulo

Through participant observation, this qualitative phase of the study recorded details of the daily activities, equipment, energy sources, and general operations of the recycling cooperative, including their collection routes, transportation, separation, and processing of the recyclable resources: plastics, paper and cardboard, glass, aluminum, and steel.

Structured interviews explored recyclers' opinions about their contribution as an environmental service provider, the importance of recognition and remuneration for their service, the efficiency of the collection, transportation, and separation activities within the cooperative and its facilities, the difficulties the recyclers experience in their work, and the idea of earning carbon credits for their environmental service. Questionnaires sent to reverse logistics companies enquired about the processing and end-use of the materials they purchase from the recycling cooperative.

Secondary data

Secondary quantitative data was collected through participant observation, literature review, and personal communications. This data included:

- Material flow data from sales ledgers provided by the *Cooperpires* cooperative, accounting all quantities, unit prices, and receipts for each type of recyclable resource commercialized in 2010, including 289.73 tonnes of plastics, paper and cardboard, glass, aluminum, and steel, shown in TABLE 4.
- CO2 emissions factors for electricity generation, and specific energy consumption for recyclable resources including HDPE/PP, LDPE, and PET/PS plastics, paper/cardboard, glass, aluminum, and steel. This data was collected from recycling, resource management and waste management literatures. All of this data is shown in TABLES 4, 5, and 6.
- Data relating to Lara landfill was obtained through local news media, the Ribeirão Pires government website, and UNFCCC CDM project literature.
- Data relating to regular municipal solid waste collection and management in Ribeirão Pires was procured through personal communications with other project members and a contact within the municipal government of Ribeirão Pires.
- Information about the wider cooperative recycling community and its stakeholders was gathered from PSWM project literature.

4.4.1 Participant Observation

Participant observation was carried out during a period of immersion in the daily activities of the recycling cooperative for the purposes of 1) learning from the recyclers how they recover, separate, process, and commercialize recyclables, and how their facility operates, and 2) to develop the necessary acquaintance with recyclers prior to conducting the interviews and acquiring secondary data from the cooperative's sales logs.

Consistent with the definition of community-based research promoted by Israel, Shultz, Parker, et al. (1998), the present research was a community-based project of practical relevance to the coop resource recovery and recycling community, responding to the request by the Brazilian PSWM project partners and resource recovery and recycling cooperative members, and was carried out within their community setting – the coop facility, the neighbourhoods they service, and the people and businesses with which they interact. The project took a participatory approach, grounded in active and reciprocal involvement of the *Cooperpires* recyclers in various stages of the research process, including their participation in the participant observation activity, the provision of material flow data, giving interviews, and member-checking.

4.4.1a Participant Observation Data

Participant observation activities took place between November 2010 and February 2011, on a 2-days-per-week rotation: one day collecting, one day separating. Written field notes were taken regarding the *Cooperpires* triage facilities; infrastructure; equipment; material flow of recyclable resources (physical capital); the cooperative's organization, capacity and efficiency in collection, transportation, and separation activities (human, social, natural and physical capitals); and the commercialization of recyclable resources (social and financial capitals).

The principal researcher participated in the door-to-door selective collection of recyclables, along the scheduled collection routes through the five residential neighbourhoods serviced by the cooperative - Santa Luzia, Vila Suissa, Estância Noblesse, Vila Aparecida, Jardim Itacolomy and Jardim Mirante – and through the city centre, collecting from businesses and public schools. Back at the transfer station, push-carts used for collection in the city centre were unloaded and the material sorted.

Participation in the separation of collected recyclable resources took place at the main triage facility. The various recyclability categories, separation procedures, processing (pressing and baling), and sale of recyclable materials were observed. Although data regarding the percentage of ultimately rejected and sent for landfill disposal were not available, casual observation showed that this amount of material is small in comparison to the quantity of material that is finally commercialized.

The active participation and interaction with the recycling community in the research process was critical to build trust among project participants, to establish co-ownership and accountability for the project, to operationalize the findings of the research, particularly the greenhouse gas accounting model, and to ensure its functionality and utility for recyclers and project members.

4.4.2 Interviews

10 structured, 10-question interviews were conducted and video-recorded with members and leaders of the recycling cooperative. Interviews took place at the triage centre and at the transfer station in the city centre, from January to February 2010. The interview questions were decided with the objective of learning from the recyclers their opinions about the efficiency of their collection and separation methods, their facility and equipment, and the general operation, as well as how they perceived the benefits that their work contributes towards environmental sustainability, and their thoughts on the recognition and remuneration of that

contribution. The day-to-day experiences of the recyclers at work provided the qualitative data for the socio-economic and socio-environmental analyses, supplementing the material flow data upon which the environmental analysis is based.

The language barrier did occasionally present a problem for the interviewer due to her minimal understanding of Portuguese and because a translator was not used during the interviews. The decision to not use a translator was based on three reasons: 1) during the participant observation period, the principal researcher (interviewer) found she was able to share basic conversation with the recyclers (interviewees), make herself understood, and understand the concepts of the conversation; 2) the scheduling of interviews was very difficult and on multiple occasions, the scheduled interviews did not take place. This situation made organizing translator unfeasible; and 3) the structured nature and the video-recorded of each interview made it possible to pose each question, allow the interviewees to answer to the extent that they wished, and then transcribe and translate the interviews after the fact with the help of a native Portuguese speaker. Although the entire interview process was not ideal, the results proved that the lack of a translator during the interviews did not have any drastic negative impact on the data collection.

4.4.3 Questionnaires

In addition to the interviews, 7 questionnaires were submitted to reverse logistics companies, specializing either in plastics (2), paper/cardboard (2), metal (2), or glass. The line of questioning for the businesses focused on type and quantities of inputs used at the plant, the energy consumption, fuel type, final end-use intended for the material, the number of employees, and the companies' dealings with the recycling cooperative. The intention was to use the company data to inform the greenhouse gas emission calculation; however, only two companies responded to the questionnaire. As both of these responding companies are strictly reverse

logistics and do not re-manufacture recycled paper products, neither of them fell within the project system boundary. This being the case, the data for remanufacturing and virgin material production had to be simulated using data from Brazilian LCA studies of recycling.

4.4.4 Greenhouse Gas Accounting

Using a CDM's approved methodology (AM) for small-scale (S) projects, *AMS III-A.J. Recovery and Recycling of Material from Solid Waste* (full and modified versions, equations [2, 3]; UNFCCC, 2011a), supplemented by the methodological tools, the *Tool to calculation emission factor for an electricity system* (equation [4]; UNFCCC, 2011b); the *Tool to calculate baseline, project and/or leakage emissions from electricity consumption* (equation [6]; UNFCCC, 2008)*;* and the *Tool to determine methane emissions avoided from disposal of wastes at a waste disposal site* (equation [7]; UNFCCC, 2011c) – this study measures the reductions in energy use and greenhouse gas emissions that are achievable through cooperative sector resource recovery and recycling. All calculations were run in the statistical computing and graphics program, *R-Studio*. Many of the default values supplied in the CDM methodologies were used in the calculations unless national data was available. For the electrical energy conversion efficiency, the emissions factor of hydropower, electric energy consumed during production, and for the adjustment factors for material degradation during production, data was obtained from the relevant literature, drawing from Brazilian studies as much as possible.

4.4.4a Data for Baseline and Project Activity Emissions Calculations

In accordance with the *AMS III-AJ: Recovery and Recycling of Material from Solid Waste*, the methodological assumption of the Baseline scenario is that it involves landfill disposal of 285.96 tonnes of recyclable resources for the year 2010 at the Lara sanitary landfill in the neighbouring municipality of Mauá, which has installed methane-to-energy technology, and is sealed with layers of compacted clay, geo-synthetic material coated with HDPE, and includes a filtration/drainage system to

ensure the maintenance of groundwater quality (Det Norske Veritas, 2005). The Baseline scenario also assumes that because these resources are not recycled, the same quantity (285.96 tonnes) of virgin resources is used in the manufacturing product chain. In the Project scenario, it is assumed that this same quantity of recyclable resources is, in fact, recycled. Landfill disposal is avoided and energy input required in the manufacturing product chain is reduced, thereby reducing the emission of greenhouse gases.

Only 285.96 tonnes of the recyclable resources are accounted for in both scenarios because although a total of 289.73 tonnes were commercialized, 3.77 tonnes of that total are 'other' recyclables (see TABLE 4). Greenhouse gas emissions for this portion were not accounted because all the items within this category are either a mixture of different materials, of which the true composition per weight of each discreet recyclable resource could not be ascertained (computer monitors/screens, motors, hose, and undifferentiated plastics), or because specific energy consumption data for production and recycling of these materials (copper, oil, and PVC) could not be obtained. The 285.96 tonnes applied to the greenhouse gas accounting model were comprised of plastic types high density polyethylene (HDPE), polypropylene (PP; consolidated into HDPE category), low density polyethylene (LDPE), polyethylene terephthalate (PET), and polystyrene (PS; consolidated into PET category), and paper/cardboard, glass, aluminum, and steel.

Below, FIGURES 3 and 4 illustrate the Baseline and Project scenarios' system boundaries, i.e., the life cycle of the recyclable resources collected by *Cooperpires*. TABLE 4 shows the types and quantities of resource used in the Baseline and Project emissions calculations, and TABLE 6 gives the various energy consumption (MWh/t) values for production.

CO_2 Emission factor of hydropower in Brazil and Energy conversion efficiency

In this study, it is assumed that hydroelectricity is supplying the energy input for all recycling processes within the Project system boundary. Brazil is highly dependent on hydroelectricity, with dams generating 80% of the country's electricity usage

Although hydroelectricity is often considered to have no associated greenhouse gas emissions, the reservoirs that are created by dams do emit CH_4 and CO_2 gases, albeit far less so than fossil fuel options (Gagnon, 1997; Weisser, 2007). The reason this range hydropower emissions factors was chosen is to account for the fact that the quantity of greenhouse gas emissions released from reservoirs depends on reservoir size, the ratio of reservoir size to power production, type and amount of flooded vegetation cover, soil type, water depth, and climate (Weisser, 2007). The highest rates of greenhouse gas emissions are found from reservoirs in the humid tropical Amazon region of Brazil (McCully, 2004), where as the Brazilian dams with lowest rate of greenhouse gas emissions are relatively small in area compared to their generating capacity (Gagnon, 1997). Dones, Heck and Hirschberg, (2004) reports an average emissions factor for Brazilian hydroelectricity of 0.34 kg CO_2-eq./kWh. The emissions factor for reservoirs in tropical climates is 0.2 – 3.0 kg CO_2-eq./kWh (Fruergaard, 2009.).

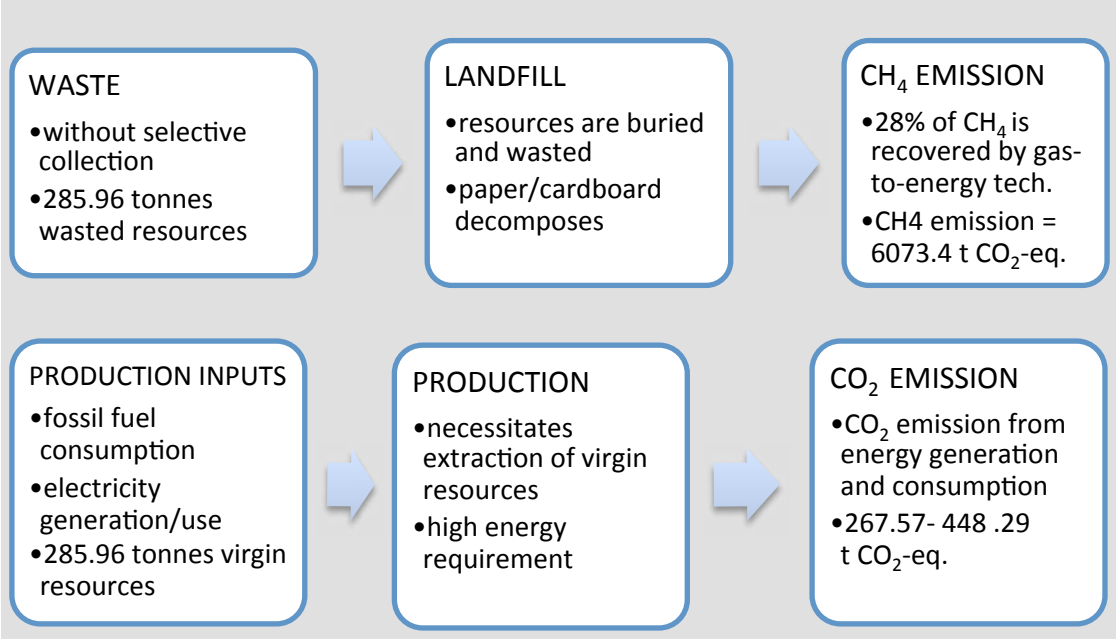


FIGURE 3: Baseline scenario: System boundary of the CDM project system

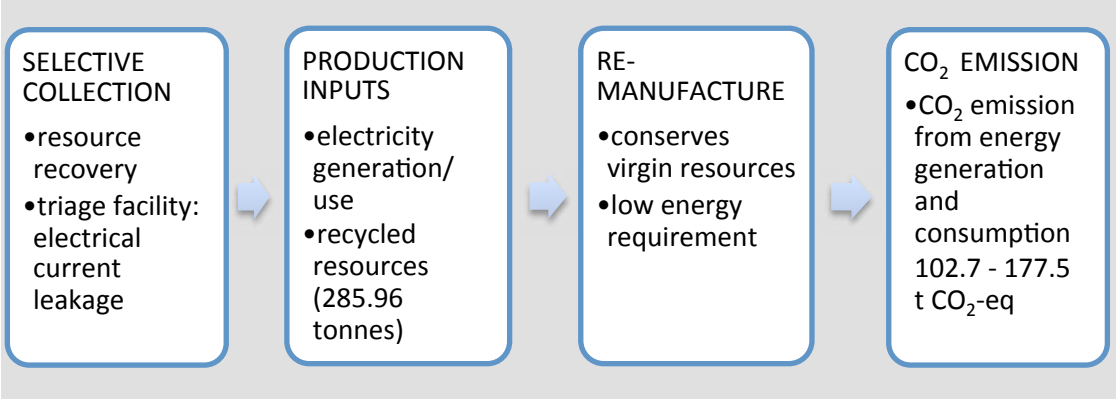


FIGURE 4: Project scenario: System boundary of the CDM project system.

TABLE 4. Types, quantities, and receipts for recyclable resources commercialized by *Cooperpires* in 2010

Recyclable resource	Index (*i*)	Quantity (tonnes) commercialized	Receipts (R$)
HDPE	1	13.42	5,405.20
PP		3.8	7,584.80
LDPE	2	18.08	7,806.20
PET	3	7.32	6,376.35
PS		2.68	422.80
Paper/cardboard	4	189.33	65,070.00
Glass	5	25.48	1,687.15
Aluminum	6	1.53	2,578.00
Steel	7	24.32	8,982.80
Other ‡		3.77	2,132.20
TOTAL		289.73	107,623.00

‡ 'Other' includes items not counted in the CDM method: computer monitors/screens, motors, hose, copper, oil, PVC and undifferentiated plastics, and 'miscellaneous'.

Ribeirão Pires' electricity is supplied by the Hydroelectric Power plant *Usina Hidrelétrica Henry Borden* on the Billings Reservoir (Empresa Metropolitana das Águas e Energia, n.d.), which is 106.6 km^2 in area, and has a generation capacity of 889 MW. The area to capacity ratio is low, and the study region has a subtropical,

rather than a tropical climate. The type and amount of flooded vegetation cover, soil type, and water depth are not known. Given the known facts, an interval of reservoir emissions of 0.2 kg - 0.34 kg CO_2-eq./kWh – corresponding to the lowest value in the range of emissions factor for tropical climate (0.2 kg CO_2-eq./kWh), and the average emissions factor for hydropower in Brazil (0.34 kg CO_2-eq./kWh) – was chosen for the variable ($EF_{CO2,m,i,y}$) used to calculate the emission factor for a grid electricity system ($\boldsymbol{EF_{el,y} = EF_{EL,m,y}}$) in equations [2, 4].

Data for the "Tool to calculation emission factor for an electricity system"

The emission factor for grid electricity generation ($\boldsymbol{EF_{EL,m,y}}$) was calculated twice using the hydropower emissions factors ($EF_{CO2,m,i,y}$) 0.2 kg CO_2-eq./KWh (0.055 t CO2-eq./GJ) and 0.34 kg CO2-eq./KWh (0.094 t CO2-eq./GJ), with an energy conversion efficiency of 90% (Rosa & Tolmasquim, 1993; IFEU, 2009).

Specific energy consumption in virgin vs. recycled resource production

Baseline emissions BE_y, for production using virgin resource inputs, and project activity emissions PE_y, for production using recycled resource inputs, were calculated in equations [2, 3] and [4]. The following specific energy consumption values $\boldsymbol{SEC_{BL,i}}$ and $\boldsymbol{SFC_{BL,i}}$ for virgin resources, and $\boldsymbol{SEC_{rec}}$ for recycled resources, were sourced from Brazilian studies by Pimenteira, et al. (2004), Gomes & Nóbrega, (2005), and Lino & Ismail (2011), for paper/cardboard, glass, metals. The CDM method default values of these variables were used for all plastic types, show in TABLE 6.

4.4.4b Data for Leakage Emissions Calculation

***Cooperpires* electricity consumption**

The *Tool to calculate baseline, project and/or leakage emissions from electricity consumption* is used to calculate the net increase in *Cooperpires'* electricity consumption as a result of leakage $\boldsymbol{EC_{LE,l,y}}$ using equation [6]. A conservative leakage current of 5.0 mA was chosen. A leakage current of 5.0 mA is the safety limit

in Canada for end users (Tyco Electronics Corporation, 2005). This Canadian datum was used because no leakage value for Brazil could be found. A medium tension of 30 – 44 kV was chosen according to AES Electropaulo (2010), because the actual tension is unknown.

4.4.5 Calculating CO2-eq Emissions Reductions

CO_2 eq. emissions reductions are determined in the following equation [1]:

$$ER_y = BE_y - PE_y - LE_y \quad \textbf{[1]}$$

Where:

ER_y Emission reductions in year *y* (tCO2e)

BE_y Baseline emissions in year *y* (tCO2e), see equation [2, 3] and [4]

PE_y Project emissions in year *y* (tCO2e), see equation [5]

LE_y Leakage emissions in year *y* (tCO2e), see equation [6]

4.4.5a Calculating $\boldsymbol{BE_y}$: Baseline Emissions

The full version of the *AMS III-AJ: Recovery and Recycling of Material from Solid Waste* method was used as it was intended for plastic types HDPE, LDPE, and PET. To account for the maximum number of plastic varieties commercialized by *Cooperpires*, plastic types PS and PP were consolidated into the categories PET and HDPE, respectively, based on "cradle-to-gate" (from resource extraction to the factory gate) energy consumption values per tonne of plastic produced, according to Hopewell, Dvorak and Kosior (2009), shown below in TABLE 5.

To calculate the baseline emissions associated with hydroelectricity and fossil fuel consumption in the production of plastics (HDPE/PP, LDPE, and PET/PS) from virgin resources, the following equation [2] is used:

$$\boldsymbol{BE_y = \sum_i \left[Q_{i,y} * L_i * (SEC_{BL,i} * EF_{el,y} + SFC_{BL,i} * EF_{FF,CO2})\right]} \quad \textbf{[2]}$$

A modified version of the method, illustrated in equation [3], was used for

data regarding paper/cardboard, glass, aluminum and steel to calculate Baseline and Project emissions associated with only hydroelectricity consumption in the production of paper products, glass, aluminum and steel from virgin and recycled resources, respectively (see TABLE 6)

TABLE 5. Categorization of plastic types by index (*i*) (and "cradle-to-gate" energy consumption (GJ) per tonne of plastic produced

Index (*i*)	Plastic type	"cradle-to-gate" energy consumption (GJ/tonne)
1	HDPE	76.7
	PP	73.4
2	LDPE	78.1
3	PET	82.7
	PS	87.4

The following equation [3] is an unofficial, modified version used to calculate the baseline emissions associated with only hydroelectricity consumption in production of paper products, glass, aluminum and steel from virgin resources:

$$\boldsymbol{BE_y = \sum_i \ [Q_{i,y} * L_i * (SEC_{BL,i} * EF_{el,y})]} \qquad \textbf{[3]}$$

Where:

BE_y Baseline emissions in year *y* (tonnes CO_2/y)

I Indices for resource type. See TABLE 4.

$Q_{i,y}$ Quantity of resource type *i* recycled in year *y*. (tonnes/year). Data from *Cooperpires'* sales ledgers. See TABLE 4.

L_i Net to gross adjustment factor to cover degradation in resource quality and material loss in the production process

of the final product using the recycled resource. See TABLE 6.

$SEC_{BL,i}$ Specific electricity consumption for the production of virgin resource type *i* (MWh/tonne). *See* TABLE 6.

$EF_{el,y}$ = $EF_{EL,m,y}$ Emission factor for the grid electricity generation, determined using equation [4]. Use 0.22 – 0.38.

$SFC_{BL,i}$ Specific fuel consumption for the production of virgin resource plastic type *i.* (GJ/tonne). See TABLE 6

$EF_{FF,CO2}$ CO_2 emission factor for fossil fuel (dry natural gas; t CO_2/GJ). Use 0.056 (Pipatti, Sharma, Yamada, Alves, Gao, Guendehou, et al., 2006)

TABLE 6. Specific electricity consumption $SEC_{BL,i}$, SEC_{rec} and specific fuel consumption $SFC_{BL,i}$, (MWh/tonne); quantity (tonnes) of recycled resources $Q_{i,y}$, and adjustment factor L_i for production with virgin vs. recycled resources.

Resource	**Virgin resources** $\boldsymbol{SEC_{BL,i}}$		**Recycled resources** $\boldsymbol{SEC_{rec}}$	**Tonnes recycled** $\boldsymbol{Q_{i,y}}$	**Adjustment factor** $\boldsymbol{L_i}$
Steel ‡	6.84		1.78	24.32	0.84
Aluminum ‡	17.6		0.7	1.53	0.9 – 1.0 *
Glass ‡	4.83		4.19	25.5	0.88 – 1.0 *
Paper/card. ‡	4.98		1.47	189.3	0.82
	$\boldsymbol{SFC_{BL,i}}$	$\boldsymbol{SEC_{BL,i}}$			
Plastics:					
HDPE/ §	4.17	0.83	0.83	16.5	0.75
LDPE §	4.17	1.67	0.83	21.9	0.75
PET §	4.17	1.11	0.83	7.3	0.75

‡ $\boldsymbol{SEC_{BL,i}}$ **and** $\boldsymbol{SEC_{rec}}$ values (Pimenteira, et al., 2004; Gomes & Nóbrega, 2005); $\boldsymbol{L_i}$ values: Rigamonti, et al. (2009), except for paper/cardboard (Merrild, et al., 2009), and aluminum (Damgaard, Larsen & Christensen, 2009). § $\boldsymbol{SEC_{BL,i}}$ **and** $\boldsymbol{SEC_{rec}}$ values and $\boldsymbol{L_i}$ values: defaults as per the methodology (UNFCCC, 2011a).

* Adjustment factor can be 1.0 for glass and aluminum because both resources can be complete recycled (closed loop) when producing the same product (e.g., used glass bottles/aluminum cans re-manufactured into new glass bottles/aluminum cans [ICF Consulting, 2005])

Tool for calculating the emission factor for an electricity system

To calculate the emissions factor for grid electricity generation ($\boldsymbol{EF_{el,y} = EF_{EL,m,y}}$) for hydroelectricity, option A2 of the CDM methodological instrument, *Tool to calculation emission factor for an electricity system* is employed. A simple operating margin CO_2 emission factor is determined based on an average efficiency and electricity generation per power plant (t CO2/MWh), by the following equation [4]:

$$\boldsymbol{EF_{EL,m,y} = \frac{EF_{CO2,m,i,y} * 3.6}{\eta_{m,y}}} \quad \textbf{[4]}$$

Where:

$EF_{EL,m,y}$	CO_2 emission factor of hydropower plant *m* in year *y* (t CO_2-eq./ MWh)
$EF_{CO2,m,i,y}$	Average CO2 emission factor of fuel type *i* used in power unit *m* in year *y* (t CO2/GJ). Use 0.2 and 0.34 (Dones, Heck & Hirschberg, 2003; Fruergaard, Astrup & Ekvall, 2009)
$\eta_{m,y}$	Average net energy conversion efficiency of power unit *m* in year *y.* Use 0.9 (Rosa & Tolmasquim 1993; IFEU 2009)
m	Power unit serving the grid in year *y.* 100% Hydropower is assumed.
y	Year as per the data vintage: 2010

Calculating $\boldsymbol{EF_{CO2,m,i,y} = EF_{el,y}}$

The calculations using equation [4] give two possible operating margin emissions factors for the grid electricity generation:

- Using hydropower emissions factor 0.2 kg CO_2-eq./KWh:

(0.2 kg CO_2-eq./KWh = 0.2 t CO_2-eq./3.6 GJ = 0.055 t CO_2-eq./GJ)

$$\boldsymbol{EF_{EL,m,y} = \frac{0.055 * 3.6}{0.9} = 0.22 \text{ t } CO_2\text{-eq./MWh}}$$

OR

- Using hydropower emissions factor 0.34 kg CO_2-eq./KWh:

(0.34 kg CO_2-eq./KWh = 0.34 t CO_2-eq./3.6 GJ = 0.094 t CO_2-eq./GJ)

$$\boldsymbol{EF_{EL,m,y}} = \frac{0.094 * 3.6}{0.9} = \mathbf{0.38\ t\ CO_2\text{-}eq./\ MWh}$$

4.4.5b Calculating $\boldsymbol{PE_y}$: Project Emissions

Calculating project activity emissions associated with energy consumption for the production of goods from recycled (secondary) materials:

$PE_y = \sum_i (Q_{i,y} * SEC_{rec} * EF_{el,y})$ **[5]**

Where:

SEC_{rec} Specific electricity consumption for recycled resource type *i* (MWh/tonne). See TABLE 6.

4.4.5c Calculating $\boldsymbol{LE_y}$: Leakage Emissions

Leakage emissions associated with the consumption of electricity are calculated using the *Tool to calculate baseline, project and/or leakage emissions from electricity consumption*, with the following equation:

$LE_{EC,y} = \sum_{\boldsymbol{i}} \boldsymbol{EC_{LE,l,y}} * EF_{EL,l,y} * (1 + TDL_{l,y})$ **[6]**

Where:

$LE_{EC,y}$ Leakage emissions from electricity consumption in year *y* (tCO2/*y*). Use **0.001 – 0.0026**

$EC_{LE,l,y}$ Net increase in electricity consumption of source *l* in year y as a result of leakage (MWh/year). Assuming a leakage current of 5.0 milliamperes and a tension of 30 – 44 kilovolts. Use 0.00456 – 0.0067 (AES Electro-paulo, 2011; Tyco Electronics Corporation, 2005).

0.005 A x 30,000 V = 0.000150 MW/ 12 h = 0.0000125 MWh * 365 =

0.00456 MWh/year;

OR

0.005 A x 44,000 V = 0.00022 MW / 12 h = 0.000018 MWh *365 =

0.0067 MWh/year

$EF_{EL,l,y}$ Emission factor for electricity generation for source *l* in year *y*

(tCO2/MWh). Use 0.22 – 0.38. See equation [4]

$TDL_{l,y}$ Average technical transmission and distribution losses for providing electricity to source *l* in year *y.* Use 0.03 (default data as per the methodology)

l Leakage source of electricity consumption. *Cooperpires* triage facility.

4.4.5d Calculating $\boldsymbol{ER_y}$: Emission reductions

Total yearly CO_2 emissions reductions, shown in TABLE 8 are determined by the following equation:

$$ER_y = BE_y - PE_y - LE_y \quad \textbf{[1]}$$

Where:

ER_y Emission reductions in year y (tCO_2 eq.)

BE_y Baseline Emission in year y (tCO_2 eq.)

PE_y Project Emission in year y (tCO_2 eq.)

LE_y Leakage Emission in year y (tCO_2 eq.)

4.4.5e Calculating $\boldsymbol{BE_{CH4,SWDS,y}}$: Avoided Methane ($CH_4$) Emissions

The greenhouse gas emissions from landfilled paper and cardboard are calculated using the *Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site.* This tool calculates baseline emissions of CH_4 from waste that, in the absence of the project activity, would be disposed of in the Lara landfill. In this equation, all variables except *f* are the default values provided in the methodology. For variable GWP_{CH4} – global warming potential for CH_4 – two values apply, 21 and 72. The justification for applying two values (in consecutive calculations) is that while the default value the UNFCCC/Kyoto Protocol decided must be applied to the equation for the first commitment period of a CDM project is 21, the lifespan of the Lara landfill is scheduled to be 21 years; therefore, a value of 72 – the global warming potential for CH_4 for a 20 year time horizon, according to Forster, et al. (2007) – is also applied to calculate CH_4 emissions beyond the first

commitment period. The equation [7] for calculation avoided CH_4 emissions is as follows:

$$BE_{CH4,SWDS,y} = \varphi * (1-f) * GWP_{CH4} * (1-OX) * \frac{16}{12} * F * DOC_f * MCF * \sum_{x=1}^{y} \sum_j W_{j,x} * DOC_j * e^{-k*(y-x)} * \left(1 - e^{-k_j}\right) \quad \textbf{[7]}$$

Where:

$BE_{CH4,SWDS,y}$	CH_4 emissions avoided from prevention of landfilling paper and cardboard (t CO2-eq./ 2010)
φ	Correction factor for model uncertainties. Use 0.9 (default data as per the methodology)
GWP_{CH4}	Global warming potential of CH_4 for the first commitment period; and for a 20 year time horizon. Use 21 and 72 (Forster, et al., 2007)
f	Fraction of CH_4 captured at the landfill. Use 0.28 (Alves & de Gouvello, 2010)
OX	Oxidation factor, reflecting the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste
F	Fraction of CH_4 from landfill that is oxidized in the soil of covering material (volume fraction). Use 0.1 (default data as per the methodology)
DOC_f	Fraction of degradable organic carbon that can decompose. Use 0.5 (default data as per the methodology)
MCF	CH_4 correction factor. Use 1.0 (default data as per the methodology)
$W_{j,x}$	Amount of paper/cardboard prevented from disposal in landfill in 2010 (tonnes). Use 189.3 (*Cooperpires* sales ledgers).
DOC_j	Fraction of degradable organic carbon by weight of paper/cardboard at 44% dry waste and 40% wet waste (tonnes). Use 76.93
k_j	Decay rate for waste type *j.* (2.71828^-0.06 = 0.5488116). Use 0.06 (Pipatti, et al., 2006)
j	Waste type: paper/cardboard
y	Year during the crediting period: 2010
x	Year during for which methane emissions are calculated: 2010

4.4.5f Energy Conservation

Using the specific electricity (and fuel, in the case of plastics) consumption variables, $\boldsymbol{SEC_{BL,i}}$, $\boldsymbol{SFC_{BL,i}}$ and $\boldsymbol{SEC_{rec}}$, as shown in TABLE , the electrical energy (MWh) conserved due to recycling 285.96 tonnes of resources was estimated by the following equation [8], and results are shown in TABLE 6.

$El_{Cons} = \sum_i (Virgin - Recycled)$ [8]

Where:

El_{Cons}	Electrical energy conserved by recycling (MWh)
i	Resource type. See TABLE 7
$Virgin$	*V* * Quantity (tonnes) of Resource *(i).* (MWh). See TABLE 7
Recycled	R * Quantity (tonnes) of Resource *(i).* (MWh/t) See TABLE 7
V	Electricity consumed in production per tonne of virgin resource type *i.* (MWh/t). See TABLE 7 $SEC_{BL,i} + SFC_{BL,i}$ where *i* = 1, 2, 3 **<u>OR</u>** $\boldsymbol{SEC_{BL,i}}$ where *i* = 4, 5, 6, 7
R	Electricity consumed in production per tonne of virgin resource type *i.* (MWh/t) = SEC_{rec}
$Virgin$	Quantity of resource type *i* * *V.* (MWh). See TABLE 7
$Recycled$	Quantity of resource type *i* * *R.* (MWh) See TABLE 7

5. Findings and Discussion

The following section discusses findings based on the data collected through participant observation, structured interviews, questionnaires, and greenhouse gas accounting methods. The first sub-section offers a brief outline of the current municipal solid waste management situation in Ribeirão Pires. Following, the participant observation, interviews and questionnaires, and secondary data yield a narrative describing the *Cooperpires* cooperative and its recycling activities – selective collection, separation, and commercialization – with consideration of the recyclers' opinions and principle researcher's observations of the organization,

infrastructure, and efficiency of the cooperative.

In the second part of this section, the results of the greenhouse gas accounting analysis and the abovementioned findings will be discussed from a capitals perspective, reflecting on the social, human, physical, financial and natural capitals embodied and produced by *Cooperpires*, as well as the recyclers' views on the cooperative recycling as an environmental service. In light of the greenhouse gas emission reductions and other capitals of *Cooperpires* recycling cooperative, the opportunity for the cooperative to participate in the CDM and engage in the carbon market is explored.

5.1 Municipal Solid Waste Management in Ribeirão Pires

This section offers a brief outline of the state of regular solid waste management services in Ribeirão Pires, followed by the findings and discussion regarding the selective collection service as provided by Cooperpires. The subsections focusing on Cooperpires begin with a narrative of its organization and infrastructure; collection, separation and commercialization processes; and the cooperative's overall efficiency in these areas. Subsequent sub-sections reveal the results of the greenhouse gas accounting method, the interviews and questionnaires, framed in a discussion on the various forms of capital – natural, social, human, physical, and financial – embodied by and generated through Cooperpires and the wider recycling actor network.

5.1.1 Regular Solid Waste Collection and Disposal

Regular solid waste collection and disposal in Ribeirão Pires is contracted out to private companies (SNIS, 2011). 100% of the population receives waste collection. 98.5% of the collected waste is disposed in the Lara sanitary landfill, 0.5% is incinerated, and only 1% in recycled (Secretary of Health and Hygiene [*Secretaria de Saúde e Higiene de Ribeirão Pires*], 2010). The total annual MSW collected was 27,453 tonnes, or 0.67 kg/capita/day, lower than the average for the urban

population in the Sate of São Paulo (0.80 kg/capita/day) (SNIS 2011). The average regular collection in 2011 is estimated at 2,366 tonnes/month, or 0.69 kg/capita/day (K. K. da Silva, personal communication, 21 November 2011), which is an increase of 3.4% over 2010. The Lara landfill is located in the neighbouring municipality of Mauá, 12 km from the Ribeirão Pires city centre, illustrated in FIGURE 5.

The expense of urban cleaning services in Ribeirão Pires, which are contracted to private firms, was R$ 4,245,947.00 in 2009 (R$ 3.15/capita/month), including collection and disposal (SNIS, 2011). ABRELPE (2008) reports that the average expense of urban cleaning services in this region of the country is approximately R$ 10.00/capita/month, R$ 3.50 – 3.75 of which is for regular MSW collection. This is slightly higher than the national average of R$ 8.93/capita/month (R$ 3.00 – 3.25 on collection). The disposal fee at the Lara Landfill is approximately R$ 73.00 tonne, costing R$ 2,004,069.00 for the city's 27,453 tonnes of disposed MSW, consuming 47.2% of the urban cleaning services budget. The diversion from the landfill of 289.73 tonnes of recyclables collected and commercialized by *Cooperpires* reduced the disposal expenses to the formal solid waste management sector by R$ 21,150.29. This cost saving demonstrates just one of the positive contributions of selective collection with respect to landfill diversion.

5.1.2 Selective Collection in Ribeirão Pires: Cooperpires Recycling Cooperative

5.1.2a Organization

The *Cooperpires* recycling cooperative is responsible for selective collection of recyclable materials from households and businesses within Ribeirão Pires, and has been operating since 2004. It currently has between 22 and 25 members, many of whom have worked together since its inception. Though the cooperative struggled much in its beginning, it is now well-equipped, financially supported, and integrated into the formal waste management system through partnership with the municipal authority, legitimized under the law 5194/08 of Ribeirão Pires. Under strong and

capable leadership, what started as an organized but informal group of recyclers has become a legally registered cooperative that is well coordinated and hard-working. Its leaders, the recyclers on collection and separation, and the truck drivers all collaborate amongst themselves, and with the businesses and residents to whom they provide their service, to extract almost 290 tonnes of valuable recyclable resources from the city's municipal solid waste stream.

As it will be shown in section 5.6, the cooperative is established in the local business and residential communities of Ribeirão Pires. It is connected to a vast actor network involving other cooperatives, the municipal government, and a regional reverse logistics industry; the regional Public Consortium of municipalities (*Consórcio Intermunicipal Grande ABC*); non-governmental and community-based organizations including the *Participatory Sustainable Waste Management* (PSWM) project, and *Coopercent-ABC*, as well as social movements including *Fórum Recicla São Paulo* (Recycling Forum of São Paulo)*, Fórum Nacional Lixo e Cidadania* (National Waste and Citizenship Forum) *,* and the *Movimento Nacional dos Catadores de Materiais Recicláveis* (MNCR; National Movement of Collectors of Recyclable Materials).

Cooperpires' progress since its founding has been enabled by multi-stakeholder collaboration and municipal support, and federal government funding and policy support for municipal selective collection schemes incorporating recycling cooperatives, including the law Nº 5194/08 of Ribeirão Pires, decree Nº 7405 Pro-Collector (*Pró-Catador)*; law Nº 11.445/2007 – National Policy on Basic Sanitation *(Politica Nacional de Saneamento Basico*); law Nº12.305/2010 – National Policy on Solid Waste *(Política Nacional de Resíduos Sólidos*); the federal Growth Acceleration Program *(Programa de Aceleração do Crescimento*), and the Ministry of Cities-National Secretary of Environmental Sanitation's Urban Solid Waste Program *(Programa Resíduos Sólidos Urbanos).*

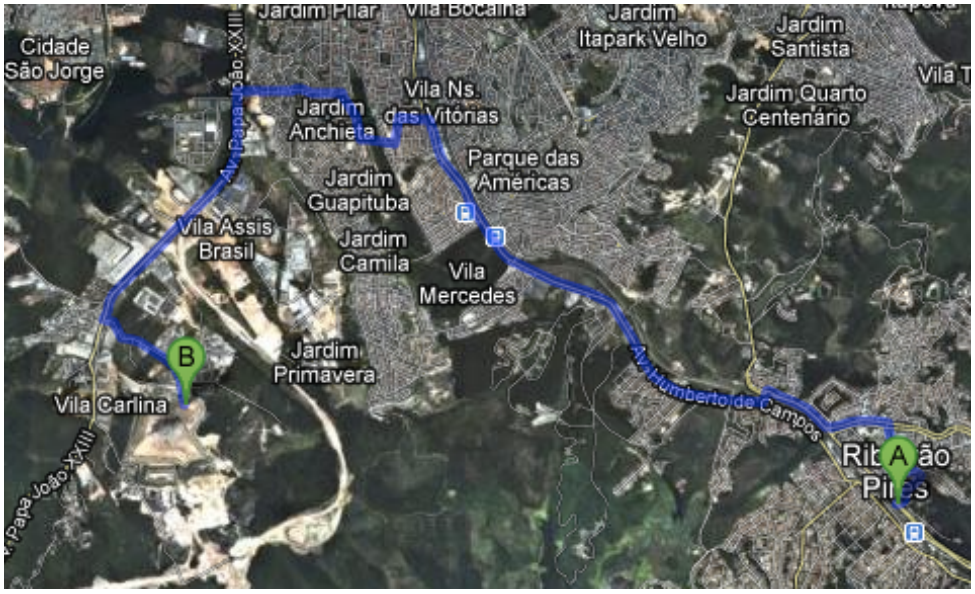
5.1.2b Infrastructure

In 2004, *Cooperpires* began operating without electricity and water, relying strictly on push-carts for collection, and had minimal triage infrastructure, and inconsistent government support. Owing to the perseverance and hard work of the *Cooperpires* recyclers and to physical capital investment (uniforms and building materials for triage tables and push-carts), and to political representation from the local business community association, *Associação Comercial, Industrial e Agricola de Ribeirão Pires* (ACIARP), *Cooperpires* was able to improve their working conditions, infrastructure, and transportation (Gutberlet 2008). It now works out of two facilities: the triage facility is the cooperative's main base and is located on the outskirts of Ribeirão Pires, about 3.9 km from the city centre, as illustrated in FIGURE 7; and a city centre transfer station, a defunct bus depot now used to store recyclables collected from local businesses by push-carts, where the materials await transport by truck to the triage facility. At the time of data collection, the triage centre was equipped with 2 hydraulic presses for crushing and baling materials, an electric forklift, a weighing scale, a long triage table on which collected materials were deposited and separated, and baffle bags into which the separated recyclables are stored until they are pressed and baled.

5.1.2c Selective Collection

Door-to-door selective collection is accomplished using a truck in the residential areas, and on foot with push-carts (FIGURE 6) for all of the city centre collection. *Cooperpires*' collection vehicles complete an average of 400 km each week to provide service coverage to neighborhoods of Santa Luzia, Vila Suissa, Estância Noblesse, Vila Aparecida, Jardim Itacolomy and Jardim Mirante, in addition to businesses, gated communities, public schools and residents who request specific collection, service coverage reaches about 8% of the city's population (S.C., interview). Although 289.73 tonnes is the quantity that was commercialized, assuming the material rejection rate is around 20% – the average rate among other

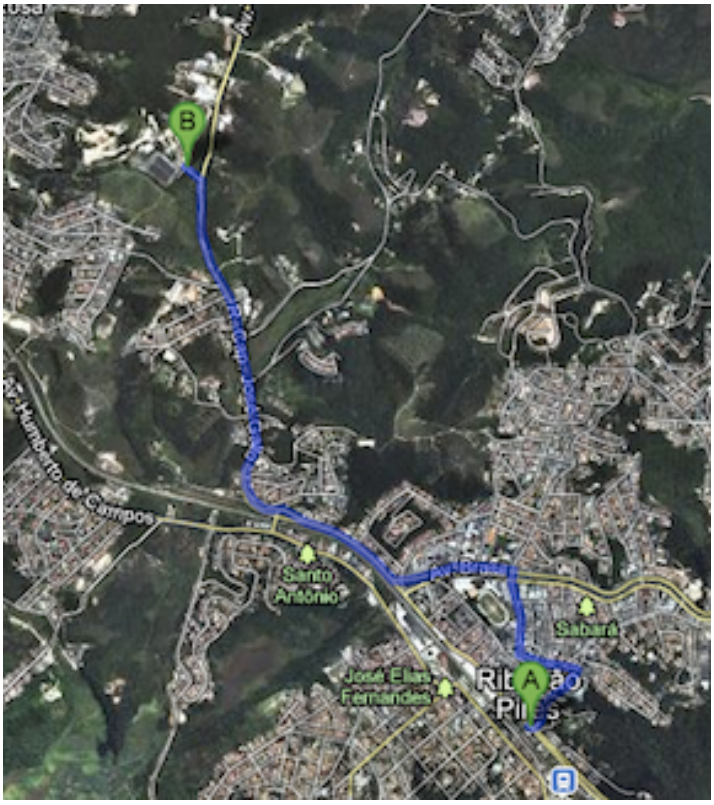
recycling cooperatives on the region, reported by FUNASA (2010) – the actual amount collected may have been closer to 350 tonnes.



(Source: GoogleEarth™)

FIGURE 5: Map of the route from Ribeirão Pires city centre (A) to Lara landfill in Mauá (B), 12 km.

FIGURE 6. Push-cart and stacks of cardboard at the city centre transfer station



(Source: GoogleEarth™)

FIGURE 7: Map of the route from Ribeirão Pires city centre (A) to *Cooperpires* triage facility (B), 3.9 km.

5.1.2d Separation

Separation of recyclable resources into their individual categories, pressing, baling, storage and commercialization, happens at the triage facility. The workers on separation duty are almost all women (usually, 8 – 9 women are at the separation table on any given day); only one elder male separates. All loading/unloading, heavy lifting, pressing and baling materials, and working the forklift are jobs occupied by men. The younger males manually transfer large baffle bags of material out of the collection truck (shown below in FIGURE 8) and onto the triage table (FIGURE 9). Some of the bags of materials only contain fairly well cleaned recyclables, while others contain recyclables mixed in with garbage that is often wet, mouldy, and odiferous, and contaminates the recyclable materials. Most of the workers wear rubber gloves and aprons to protect themselves against possible cuts and infections from sharp objects and bacteria.

FIGURE 8. The men of Cooperpires unloading recyclables from the collection truck at the *Cooperpires* triage facility.

The various recyclable materials were separated into their respective categories, including white office paper, mixed paper, cardboard, tetra pak, plastics, glass, aluminum, other non-ferrous metals, ferrous metal, wood, bulky items and re-usable items that the workers often reclaimed and took home, such as clothing, toys, utensils, appliances, and toiletries. Plastics are sorted into multiple categories including LDPE, HDPE, PET, PP, PS, and PVC. These categories are then further differentiated into sub-categories by colour, weight, or product type, e.g., soft, light-weight yogurt pots and disposable cups from heavier, more rigid plastics; 2 L cola bottles from other PET; clear plastics from coloured plastics, etc. Overall, plastics were separated in 15 distinct categories.

FIGURE 9. The women of Cooperpires separate the recyclables spread out on the triage table.

5.1.2e Commercialization

In 2010, *Cooperpires* commercialized 289.73 tonnes of recyclable materials, 0.62% of total municipal solid waste generated by the population of Ribeirão Pires. Selling to reverse logistics companies local to surrounding municipalities, the cooperative earned R$ 107,624.93 (around CA$ 60,000.00), just over R$ 407.66/month per recycler. This income has increased since a reported average monthly earnings of R$ 350.00 – 360.00 (FUNASA 2010; Gutberlet 2009) per recycler for cooperatives in the ABC region, including Cooperpires. However, it is still below minimum wage in São Paulo, which by law Nº 12.382 of 2011 is R$ 600.00 (CA$ 348.00). The interviewees stressed the importance of recycling as a livelihood, and of the cooperative as a source of secure employment, pointing out that the cooperative provides jobs for people who are excluded from the labour market due to lack of qualifications or because of their age.

Gutberlet's earlier research (2008) with the cooperative in 2005 showed that the recyclers were at that time earning only R$ 50.00/month, an income less than one fifth of the official minimum wage of R$ 260.00 in January of that year (MTE-SENAES, 2011). Today, *Cooperpires* members earn an average of over

R$ 400.00/month – eight times what they were earning in 2005. The now-formalized cooperative offers secure employment for the 24 people that worked in the cooperative during the research period, as well as 30 new positions recently created within the cooperative (Government of Ribeirão Pires [*Prefeitura Municipal da Estância Turística se Ribeirão Pires*] 2011).

Reverse Logistics Industry

The two questionnaire recipients who responded are both reverse logistics companies local to the region, specialize in paper/cardboard, and act as middlemen between *Cooperpires* and re-manufacturers. These companies sell bales of crushed and shredded cardboard and paper as raw material for new paper products. Between the two companies, 68 people are employed, including truck drivers, forklift operators, manual labourers, and a quality inspector (at the larger of the two plants), demonstrating the industry's value as a source of jobs.

The companies purchased a total of 189.3 tonnes of pressed and baled white and mixed paper, and cardboard from *Cooperpires* in 2010 – 65.3% of the cooperative's total material yield. The dominance of this resource type in the overall composition is due to the cooperative's city centre collection from businesses. *Cooperpires'* commercialized paper/cardboard constitutes about 1% of all such material handled by the companies, and while one company perceived no difficulty in obtaining this material, the other company complained about contamination of material due to the low participation rate for source separation. This speaks to the importance of publicity and public education about selective collection.

5.1.2f Efficiency

The cooperative has seen a 500% increase of their selective collection yield in their 6 years of operation, from 10 tonnes to approximately 50 tonnes per month. Although efficiency is not optimal, the cooperative does as much as possible within the space, and with equipment they have. *Cooperpires* is always improving and

increasing collection yield. Replacing the manual press with the hydraulic press increased the efficiency of pressing and baling materials from 60 kg to 150 kg per bale (shown in FIGURE 10). With more space, and more staff collecting and separating, *Cooperpires* could process more material, especially cardboard (F.C., interview, 2010). Additional equipment – a paper shredder and a PET pellet mill – expected in the future will further improve efficiency and add more value to their product (J.C., interview, 2010). A paper shredder makes the material easier and faster to press, with better compaction and transportability. The PET pellet mill will allow *Cooperpires* to exploit other avenues of commercialization, increasing the number of companies with which they trade.

FIGURE 10. Making bales of pressed cardboard in the hydraulic press.

The cooperative is in need of more workers. Just as there is not enough infrastructural capacity, neither are there enough workers for the amount of material being collected; an amount that is continually increasing. There is also need of an extra truck and driver. The two truck drivers are municipal employees, not cooperative members. There is the feeling among cooperative members that it may

improve coordination and cooperation between collection and transport if the trucks belonged to Cooperpires, and their drivers were cooperative members.

Among the 10 – 13 women and 10 – 12 men that worked at the cooperative throughout the study period, there is a gender division of labour. 83% of the women working almost exclusively in separation, while 80% of the men worked exclusively in collection. *Cooperpires'* members claim that the gender division of labour works well, because the men are faster and strong when it comes to collection, and the women are better at separation. Both men and women do collection, however, only the males use the push-carts in the city centre and do the majority of the collection there. Generally, the women do most of the residential collection, following on foot behind the truck, gathering the bags of recyclables from the curbside. One or two men stay inside the container of the truck, accepting and organizing the collected bags and loose items, loading and unloading the material manually.

The triage facility infrastructure was inadequate in terms of the cooperative's operation and, as such, had built-in inefficiencies due to space constraints, security, and occupational health. The building was not secure; it was dirty and leaky, posing health risks and general discomfort and inconvenience. The kitchen, toilets and change rooms were at times without working lights, functioning toilets, or running water.

The greatest efficiency concern was over the size of the building and the infrastructure. The triage facility was far too small for the quantity of material the cooperative accumulates, estimated to be up to 40 – 60 tonnes of recyclables per month (*Secretaria de Saúde e Higiene de Ribeirão Pires*, 2010). According to the *Cooperpires'* sales ledgers for 2010, the average monthly sale is 24.14 tonnes of clean, separated, pressed and baled recyclable resources (the composition of which is show in FIGURE 11), which means that, after the separation has removed the waste from the collected materials, the remaining recyclable resources are stockpiled, occupying precious space while awaiting sale. Stacked bales of pressed

materials lined the walls of the triage facility; the floor barely accommodates the many large baffle bags containing their respective resources. Often, the cooperative collected more material that they had they physical capacity for, leaving very little room to maneuver the baffle bags or even to walk around, and forcing bags of pre-sorted material to be left outside the building, infringing on the already limited loading area.

This situation had several unfortunate consequences. First, it is an efficiency bottleneck, restricting the cooperative's capacity to collect and process recyclable resources. Second, outside storage degrades the quality of the recyclables. Heavy rains, typical of the region, make any uncovered paper and cardboard unsaleable. And third, it vexes the other residents in the neighbourhood, arousing the 'not in my back yard' (NIMBY) sentiment. In fact, the cooperative suffered an arson attack on their facility during the research period, in which bags of material left outside were set on fire. It is assumed this act was committed in retaliation by neighbors who had taken issue with the external presentation of the Cooperpires facility.

Perhaps, the cooperative's lack of infrastructural capacity and the efficiency bottleneck and NIMBY-ism it creates, will finally be remedied in 2012 when *Cooperpires* opens a new, 600m^2 triage facility with a capacity of 550 tonnes, conveniently situated beside the current facility. This additional space will allow the cooperative to expand the selective collection service to neighborhoods that are not yet covered, and open 30 new jobs. Additional service coverage and staff will increase efficiency of the cooperative as an environmental service.

Data on one important efficiency indicator was not collected, that being the amount of rejected materials separated out from the recyclable stream and sent to landfill disposal. Rejection of recyclable materials is usually a result of contamination due to mixing of recyclables with waste materials (as noted by one reverse logistics questionnaire respondent) or, as mentioned previously, due to improper storage of collected materials. Contamination is an efficiency barrier as it

compromises the quality of the recyclable resources. The cooperative did not keep a consistent record of their waste ouput for 2010. However, an estimate can be made based on generation rates from over 33 recycling cooperatives in the São Paulo Metropolitan Region and surrounding area (FUNASA 2010; Lino & Ismail 2011) that the cooperative likely rejects approximately 20% of collected material, or about 58 tonnes in 2010. An improvement in this particular efficiency indicator would be achieved by greater public education on what items are recyclable and accepted by Cooperpires, as well as by an ancillary recycling scheme for items such as styrofoam, wood, and furniture (J.C., interview, 2010).

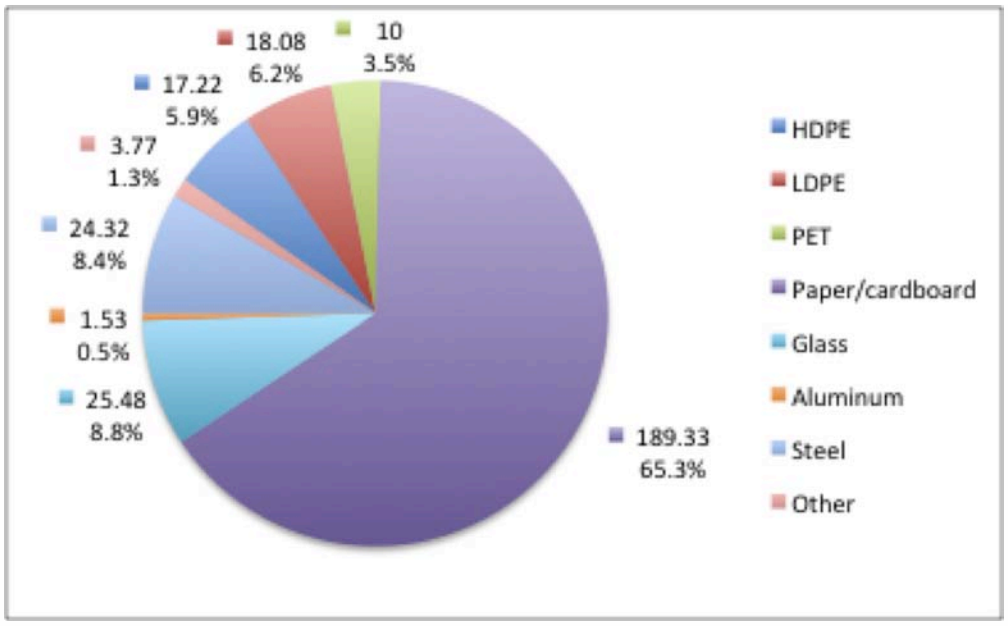


FIGURE 11. Composition of recyclable resources commercialized by Cooperpires in 2010, by weight in tonnes and percent of total.

5.6 Cooperpires: Embodied and Generated Capitals

The study's findings show that the *Cooperpires* recycling cooperative possesses the necessary capital required for long-term sustainability as a selective collection and recycling service provider. It also creates capital – natural, social, human, physical and financial – through the collection, processing and commercialization of

recyclable resources, and through its interconnectedness with the communities and partners it services, trades, or collaborates with. The interviewed members of *Cooperpires* are keenly aware of the multiple beneficial outcomes of their work including urban cleanliness, the health of waterways, prevention of dumping and burning MSW, and landfill diversion; resource conservation through valorization of recyclable materials as resources; the addition of value through separation, pressing and baling; and last, but not least, job creation and income generation. *Cooperpires* member, M.C., had the following to say: *"Yes, we are helping maintain a clean city and environment ... I think that my contribution is helping a lot [to avoid] material be thrown in places where it can clog drains and cause floods... I want Ribeirão Pires to improve the collection [because] it is a benefit not only for us who collect, but for the population of Ribeirão Pires."* (M.C., interview). The following section looks at the benefits generated by and for *Cooperpires* recycling cooperative with respect to all the capital it embodies, as well as the capital it creates through its activities and the recycling actor network.

5.6.1 Natural Capital

The recycling cooperative generates natural capital through resource recovery. It is a multi-dimensional environmental service that not only promotes health of the urban and natural environments, as mentioned above, but also makes a valuable contribution to greenhouse gas emission avoidance through energy conservation and landfill diversion.

5.6.1a Energy conservation and greenhouse gas Emissions Reductions

Energy conservation

The daily operations of the cooperative's triage facility consume an average of 1.97 MWh/month to produced 24.14 tonnes/month of separated, pressed, and baled recyclable resources in 2010. For a total of 289.73 tonnes, the facility's electricity consumption is 0.0816 MWh / tonne of separated, pressed, baled, and commercialized recyclable resources, while the energy conserved by the

remanufacturing of 285.96 tonnes of this material is an average of 3.62 MWh (13 GJ)/tonne. As illustrated below in TABLE 7, the total amount of energy saved (El_{Cons} in equation [8]) by the recycling of by *Cooperpires* was 1034 – 1035.3 MWh in 2010.

TABLE 7. Electricity (MWh) used in production per tonne (t) of virgin and recycled resources, and total electricity conserved (El_{Cons}) by recycling

Resource (i)	Quantity t	V MWh/t	$Virgin$ MWh used	R MWh/t	$Recycled$ MWh used	El_{Cons} Total MWh	El_{Cons} MWh/t
HDPE/PP (1)	17.22	5.0	86.1	0.83	14.3	71.8	4.17
LDPE (2)	18.08	5.84	105.6	0.83	15	90.6	5.0
PET/PS (3)	10	5.28	52.8	0.83	8.3	44.5	4.45
Paper/ cardboard (4)	189.3	4.98	942.7	1.47	278.3	664.4	3.5
Glass (5)	25.5	4.83	123.1	4.19	106.8	16.3	1.6
Aluminum (6)	1.5	17.6	26.4	0.7	1.1	25.3	16.9
Steel (7)	24.3	6.84	166.2	1.78	43.3	122.9	5.0
TOTAL	285.96		1502.84		467.1	1035.74	3.62

Greenhouse gas emission reductions

The results of the CDM greenhouse gas accounting method show that resource recovery and commercialized by *Cooperpires* contributed to an emissions reduction of 6241.6 – 6343.2 t CO2-eq. (168.2 – 269.8 t CO_2-eq. through recycling, and 6073.4 t CO2-eq. through landfill diversion of paper/cardboard [calculating $BE_{CH4,SWDS,y}$ using a GWP_{CH4} value of 72]) in 2010. This amount is equal to 21.8 – 22.2 t CO2-eq./tonne of all resources recycled. The CO_2 emissions reductions achieved by recycling each individual resource are shown below in TABLE 9, and can be compared to TABLE 3, showing various other studies' estimated greenhouse gas emission reductions from recycling. For the first commitment period as a CDM project, the achievable CERs from avoided landfilling of paper/cardboard (based on a $BE_{CH4,SWDS,y}$ calculation using a GWP_{CH4} value of 21) would be only 1771.4 t CO_2-eq., lowering the total emissions reduction to 1939.6 – 2041.2 t CO_2-eq., or 6.7 – 7.05 t CO_2-eq./tonne of recyclable resources.

TABLE 8. Baseline emissions, Project emissions and Total emission reductions (t CO_2-eq./year), by resource type (t CO_2-eq./tonne), and $EF_{el,y}$ variables

$EF_{el,y}$ (tCO_2/MWh)	***0.22***	***0.38***	***0.22***	***0.38***	***0.22***	***0.38***	**Emissions reductions**
Resource type (*i*)	**Baseline Emissions BE_y**		**Project Emissions PE_y**		**Emissions reductions ER_y**		**t CO_2-eq/ tonne (*i*)**
LDPE (1)	13.2	14.91	3.14	5.43	10.06	9.48	0.4 – 0.43
HDPE (2)	16.3	20	3.3	5.7	13	14.3	0.98 – 1.08
PET (3)	8.12	9.45	1.82	3.15	6.3	6.3	0.63
Paper/card. (4)	170.1	293.8	61.2	105.76	108.9	188.04	0.58 – 0.99
Glass (5)	27.1	46.8	23.5	40.6	3.6	6.2	0.14 – 0.24
Aluminum (6)	5.33	9.2	0.23	0.4	5.1	8.8	3.40 – 5.87
Steel (7)	30.7	53.1	9.5	16.45	21.2	36.65	0.87 – 1.51
TOTAL	**270.85**	**447.26**	**102.69**	**177.49**	**168.16**	**269.77**	**0.59 – 0.947**

α Equation [1] $ER_y = BE_y - PE_y - LE_y$. For LE_y values, see BOX 2., Section 4.3.5c

Paper/cardboard accounts for almost 69.4% of the greenhouse gas emission reduction achieved through Cooperpires' efforts and the reverse logistics industry. And, it accounts for 98.7% of the total greenhouse gas emission reduction as a result of the entire recycling system (i.e., all recycling efforts including, selective collection, remanufacturing and landfill diversion). If we consider the position of the US EPA (2008), which contends that carbon sequestration in forest biomass is increased through paper/cardboard resource recovery and recycling, and has been calculated to yield -0.83 t CO_2 eq. per tonne of material recovered, then *Cooperpires* affects an additional reduction of 157.14 t CO_2-eq. due to carbon sequestration. This addition increases Cooperpires' total greenhouse gas emission reduction to 6398.7 – 6500.34 t CO2-eq./year, which is a reduction of 22.4 – 22.7 t CO2-eq./tonne of resources recycled.

5.6.1b Drawbacks of the CDM Methodology for Cooperative Sector Recycling

In terms of accuracy, there are drawbacks to using the CDM methodology, as opposed to performing a full-scale LCA, for assessing greenhouse gas impacts of recycling. Whereas an LCA requires a life cycle inventory analysis in which data on all the activities, inputs and outputs in the product system are collected, and corresponding environmental loads (resource use and pollutant emissions) are calculated (an even then, as discussed in section 3.3.1, conditions of uncertainty are a key consideration), the CDM methodology, *AMS III-AJ: Recovery and Recycling of Material from Solid Waste,* does not call for any such life cycle inventory analysis. The methodology is focused solely on energy input and resultant greenhouse gas emissions, therefore ignoring other inputs and processes of the life cycle. Another drawback of the method is that the official version is currently limited to use for plastics. Calculating greenhouse gas emission reductions for recycling of paper/cardboard, glass and metals required an unofficial modification to the method (see section 4.4.5a, equation [3]), creating uncertainty as to whether the results of the modified version are, in fact, comparable to the results of the official version.

Yet another concern is that both the *AMS III-AJ* and the *Methodological tool to determine methane emissions avoided from disposal of wastes at a waste disposal site* partially rely on the use of default values, and while it is necessary to use default values in the case where local data is not available, defaults tend to err on the side of caution, providing only the most conservative estimates. Fruergaard, Astrup & Ekvall (2009) reports that electricity use and emission factors have a big impact on greenhouse gas accounting results, an impact that is evident in the difference between the two emissions factors – 0.2 kg and 0.34 kg CO_2-eq./kWh – used in the present greenhouse gas analysis and reflected in a large variation in total emission reduction of more that 90 t CO2-eq./year. Thus, the default value for Brazil electricity production provided by the IFEU *SWM-GHG Calculator*, 0.051 kg CO_2-eq./kWh, would produce very different results than those calculated in the present study.

5.6.2 Social and Human Capitals

The study's findings show that the *Cooperpires* recycling cooperative possesses the necessary capital required for long-term sustainability as a selective collection and recycling service provider. The cooperative's success in this endeavor can be attributed to its connections within an actor network of mutual stakeholders including the municipal government's Department of the Environment and Basic Sanitation (*Secretaria do Verde, Meio Ambiente e Saneamento Básico* [SEVEMASA]), the residential community and business communities of Ribeirão Pires, the reverse logistics industry of Ribeirão Pires and surrounding municipalities; the *Coopcent-ABC* (a central "cooperative of cooperatives"); the national recyclers movement (*Movimento Nacional dos Catadores de Materiais Reciclaveis*); the University of Victoria, Canada, and the University of São Paulo; the *Intermunicipal Consórcio Grande ABC* (Intermunicipal Consortium of the Greater ABC region of São Paulo; hereafter referred to as the Intermunicipal Consortium), and the municipal governments of Santo André, Diadema, Mauá, and Ribeirão Pires.

5.6.2a Social Capital

The recycling cooperative *is* and can create social capital. Social capital within the cooperative is maintained and enhanced through its interconnectedness with its fellow advocates of cooperative recycling, such as the PSWM project, the Inermunicipal Consortium, *Coopercent-ABC*, social movements, and several other recycling cooperatives in the ABC region of São Paulo. This social capital is essential to the generation of all other forms of capital. Of particular note are the PSWM project and Intermunicipal Consortium. The interaction between these two entities and *Cooperpires* is social capital at work. Human, financial and physical forms of capital are functions of this social capital.

Throughout its six year run, the PSWM has provided capacity-building training and workshops to recyclers, and has worked to create a space for dialogue and knowledge exchange between recycling cooperatives and other stakeholders. In

this respect, the PSWM has been instrumental in facilitating dialogue between *Cooperpires* and the Intermunicipal Consortium, as well as between *Cooperpires* and the municipal government of Ribeirão Pires. Both the Intermunicipal Consortium and the PSWM have raised awareness and support for inclusive waste management, and have enabled debate and the dissemination of information among stakeholders, as well as the mobilization of resources.

Environmental social capital

Social capital is also created through *Cooperpires'* interaction with the communities it serves. An exchange between the recyclers and other community members creates what Figueroa (1998) referred to as 'environmental social capital', that is, a symbiosis between social and natural capital. Collecting door-to-door generates the opportunity for recyclers to disseminate their knowledge about the social and environmental roles of resource recovery and recycling throughout the neighbourhoods they service. This community connection acts to affect positive outcomes (still a market externality for the most part, except where carbon finance has commodified the avoidance of greenhouse gas emissions) for the urban and natural environments (Roseta-Palma, et al., 2010). One *Cooperpires* member offered, *"I like to do [collection], I think that everyone likes to do collection … we have a lot of communication with the people ... because of the door-to-door. We have more contact, are able to ... connect with the products we seek ... No more throwing it in the street, in the drain, in the river."* (D.C., interview). Towards this end, the municipal authority of Ribeirão Pires and the local media work together with the recyclers to increasing the recyclers' public profile, to raise the citizens' awareness of the cooperative and its service, and to broadcast the importance of the citizens' participation in the selective collection program.

Members of the cooperative report that a growing number of the city's population express their appreciation for the recyclers' work, instead of the criticism offered in the past (although that has not disappeared). Besides the collection of recyclable materials, there is also a network of sharing information about selective collection,

and the exchange of re-usable goods – appliances and electronics, clothing, books, furniture, and sundries – between the recovery/recycling community and members of the broader community.

5.6.2b Human Capital

The recycling cooperative is a source of human capital; the recyclers' possess knowledge of valuable recyclable resources and the market demand, and competency in adding value to and commercializing those resources. Recognition of this human capital is a necessary precursor to inclusive solid waste management, and supports the recyclers' right to dignified work (Gutberlet 2012). Human capital is enhanced through the recyclers' organization as a cooperative, and through training and capacity building activities such as those offered through the PSWM project: seminars and workshops on the development of leadership, communication, and management skills, as well as specific technical abilities. Organization and capacity building empowers recyclers in securing their livelihood, autonomy, social inclusion and participation in policy formation, improving their quality of life and fostering self-esteem (Tremblay & Gutberlet, 2010).

Self-esteem in an aspect crucial to recyclers' wellbeing, reflected by comments of two of *Cooperpires'* senior members that the stigma and sense of shame associated with the work of resource recovery from waste are among the great problems that recyclers face, commenting, "*What's important is we bring work to the people who are out of the labour market. Many people, due to misinformation, think that it's disgusting, think that to work in waste is awful. And this is one of the worst problems: one is embarrassed."* He goes on to say, "[Cooperpires] *is evolving slowly, the process is slow [but] the tendency is continuous improvement… This here is only the beginning. But from here to 10 – 15 years, you will see the value that [the public] will give to the recycler… they will accept [recycling]."* Recognition of the environmental and social importance of their work has a significant impact not only on the recyclers' self-esteem, but also in terms of their social inclusion and their livelihood.

5.6.3 Financial and Physical capital

Cooperpires has received financial and physical capital from a variety of sources including the PSWM project, ACIARP, and the municipal and federal governments. The PSWM was a partnership project between the University of Victoria, Canada, and the University of São Paulo, that ran from 2005 to 2011. It received funding from the Canadian International Development Agency (CIDA), and that financial capital was invested towards assisting *Cooperpires* (as well as many other recycling co-operatives in the Metropolitan Region of São Paulo) with capacity-building, organization and networking, enhancing recyclers' efficiency and safety, and facilitating the collective commercialization of recyclable resources. Physical capital was donated by ACIARP, as previously mentioned, in the form of uniforms and building materials for triage tables and push-carts.

Significant physical capital and financial capital have been invested into *Cooperpires* by the municipal government of Ribeirão Pires, which has supported the recycling cooperative's resource recovery operation through the donation of 2 trucks with drivers included, the triage facility building, and machinery. This investment and their partnership has been crucial for the survival of the cooperative, a reality that is reflected in the statement by a *Cooperpires* member: *"The [municipal government] helps with the donation of 2 trucks for collection, because without them there is no way; we wouldn't realize much material. [And] we have a specific place to keep this material because the government is helping… It is helping not only the environment, but also to guarantee our salary."* (M.C., interview). The cooperative also receives INSS (Brazilian social security), health and other benefits. *Cooperpires* is now considered a model by the São Paulo state government (UNISOL Brasil 2011).

In 2011, the cooperative took up occupancy in a new 600 m^2 triage facility, built with $ 277,500 funding from the federal government's *Programa de Aceleração do Crescimento* (Growth Acceleration Program). The building has a large separation

area, an office, locker rooms (including showers) and bathrooms, a kitchen and a training room (UNISOL Brasil, 2011). A larger triage centre will allow the cooperative to expand the selective collection service to neighborhoods that are not yet covered, and open 30 new jobs. Aiming for a 10% landfill diversion rate, the cooperative was reported to have achieved a landfill diversion rate of 1.5% in first half of 2011. Currently, the door-to-door selective collection brings in up to 40 tonnes of material per month (*Secretaria de Saúde e Higiene de Ribeirão Pires*, 2010), with an average sale of 24.14 tonnes of clean, separated, pressed and baled recyclable materials per month, according to the cooperatives sales ledgers for 2010. There is also the downstream financial benefit of the cooperative's social capital, in that networking with *Coopcent-ABC* creates the opportunity and provides the necessary support for the acquisition of equipment (Coopcent-ABC, 2011), and for to ensure that the recyclers are fairly remunerated for their product (Gutberlet 2009; Yates & Gutberlet, 2011).

The critical importance of both financial capital and physical capital is the reason why exploring the opportunity for recycling cooperatives to engage in the carbon credit market is a logical next step in their development as an environmental service provider. Considering the obvious commitment by the São Paulo State Government and by the Federal Government to climate change mitigation through participation in the CDM, and the commitment by municipal governments to the development of recycling and integrated solid waste management, it is not unrealistic to hope that integrated recycling cooperatives will find support for their participation in CDM projects.

Fortunately for recyclers in Brazil, municipal action is facilitated by the relatively high degree of political, administrative and financial autonomy of municipal governments. As noted by Davey (1996), Brazilian municipalities may be among the most comprehensive and independent in the world, in comparison to many other low- and middle-income and even high-income nations. Municipalities in Brazil have the power to determine their own municipal constitution (*Lei*

Orgânica), and to determine their own organization and functions (Acioly, 2001), including how policies and legislation regarding municipal waste management and climate change mitigation are synchronized and enacted.

5.7 Cooperative Recycling: Potential Benefits as a CDM Project

With respect to *Cooperpires* – or any recycling cooperative in the ABC region of São Paulo – gaining CDM project approval and participating in the carbon market, the Intermunicipal Consortium may be one of the most important bodies of governance to assist the cooperative in this process. The Consortium stands as an example, albeit on a much smaller scale, of what Selin (2011) refers to as a Regional Center, a body intended to connect global policy goals with local management needs. The Intermunicipal Consortium began as a civil association in 1990. In 2005, it became a Public Consortium as per the federal law No. 11107, and part of the indirect administration of associated municipalities, entitled to plan and execute public and regional policy actions.

Regional Centres such as the Intermunicipal Consortium can assist with resource mobilization, finding and dispersing adequate financial and technical resources. They can also aid legislation monitoring and compliance. In the case of the ABC region of São Paulo, the geographic scale is intermunicipal, rather than international; however, the purpose of the Regional Center is still fulfilled. There is potential for the Intermunicipal Consortium to act as the Regional Centre linking recycling cooperatives, the municipal governments of the Metropolitan Region of São Paulo, and the CDM Designated National Authority.

Together, this network of stakeholders show how partnerships, multi-stakeholder action, deliberative democracy, political, financial and social support realize not only local waste management needs, but also fulfill many of the Millennium Development Goals. By investing in the livelihood of recyclers through collaborative action, financing and supportive public policy, the following

sustainable development goals are being achieved:

- Reduction in vulnerable employment (achieve full and productive employment and decent work, with adequate social protection and fair pay)
- Reduction in gender disparity (female empowerment through leadership positions at coops);
- Poverty alleviation,
- Improvements in public health, living and working conditions,
- Integration of sustainable development principles into national policies and programs,
- Conservation of environmental resources (UN 2011).
-

At present, the *Cooperpires* recyclers are well aware of the many important environmental benefits such as keeping wastes out of the rivers, preventing pollution and flooding; preventing the uncontrolled dumping and burning of waste; and keeping the natural and urban environments clean. Pride in this aspect of the recyclers' work is evident in many of the interview responses. The climate change mitigation impact of their work, however, is not yet a part of the recyclers' perception of environmental benefits. Only one of the leaders expressed familiarity with the term *carbon credits*, expressing a need and desire to learn about this potential source of income. In this respect, it is possible that the Intermunicipal Consortium and the PSWM project partners, the University of Victoria and the University of São Paulo, can play a future role in the dissemination of accessible information on these topics, and can provide the recyclers with the training (harnessing and enhancing human capital within the cooperative) and support that would be necessary should the cooperative decide to apply for and achieve CDM project approval.

A sustainable CDM project must address the needs of marginalized and poor people. The people who make their living from resource recovery and recycling waste are important stakeholders in the municipal solid waste management system. It should be ensured that they are included in all discussions and consultations

regarding municipal waste management plans, and that they do not lose out under an integrated waste management system (Gonzenbach & Coad, 2007). Municipal waste management and climate change mitigation policies and legislation must be designed and enacted in a way that safeguards the existing jobs of informal and cooperative sector recyclers, and creates additional jobs as well as support for the formation of cooperatives, and preferential awarding of contracts to this sector for the provision and administration of selective collection programs. This is key for moving towards social inclusion and poverty alleviation, as illustrated in the following comment by one of the Cooperpires leaders: *"This year [2010],* Cooperpires *achieved many victories… It's very important because I depend on it; I don't have another way to earn. Already I am of an age that no one [else] will hire me, so [I have] only this work. And I like this work. I take my livelihood [from it]."* D.C., interview). The financial investment from a CDM project partner (domestic or foreign), and additional income from carbon offsets, would go some way to ensuring that such opportunity for employment and income persists. It would contribute substantially the development of social, human, financial and natural capitals that were discussed in chapter 2, including:

- Social and human development; dignity, self-esteem, and empowerment;
- Economic growth and the development of the reverse logistics and recycling industries; and
- Realization of climate mitigation and waste management objectives.

6. Conclusion

Cooperpires recycling cooperative possesses and created essential capital in various forms, the investment and utilization of which has virtuous positive feedback for the cooperative, and all other stakeholders involved. Cooperpires is an example of a recycling cooperative working in partnership with the multiple stakeholders towards a 'triple bottom line' sustainable, integrated municipal solid waste management service. This case study adds weight to the findings of previous

authors that policies, programs, and legislation supporting informal/cooperative sector participation in an integrated municipal solid waste management system through partnerships involving the municipal authorities, and/or with NGOs and CBOs, and the private sector, can and does make significant improvements to the quality and extent municipal solid waste service provision.

This case study shows that a significant reduction in greenhouse gas emissions is achieved through cooperative recycling; an environmental benefit that can be heightened through increased public participation in source separation of recyclables, a larger staff of recyclers within the cooperative, and additional equipment. Greater social and economic benefits can be achieved if *Cooperpires* is supported in gaining approval as a CDM project. It is possible that this achievement may further the socio-economic inclusion of the recyclers by increasing their income and enhance the cooperative's role in social inclusion and poverty alleviation. Such environmental and socio-economic outcomes are in line with the UN Millennium Development Goals, which focus development efforts on poverty alleviation, equitable and inclusive economic growth (UN 2011).

Government support for informal/cooperative sector recycling and the co-management of recyclable resources is crucial to the realization of 'triple bottom line' sustainable, inclusive, integrated municipal solid waste management service in Ribeirão Pires and across the Metropolitan Region of São Paulo. The protection of recyclables resources as a commons accessible to informal/cooperative sector - unenclosed by corporate interests - is to ensure that those people working in the informal/cooperative sector, providing this service to communities in cities all over the world, are not further impoverished in the process of integrating resource recovery and recycling into formal sector municipal solid waste management.

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Appendix 1: Interview questions for Recyclers

1. What role do you think your recycling coop plays in environmental sustainability?
2. Does your facility currently run at maximum capacity?
3. Are there specific barriers that prevent the coop from achieving maximum capacity?
4. How efficient is the collection process?
5. How does the coop's transportation affect the coop's productivity?
6. How efficient is the separation process?
7. How does the coop's equipment affect the coop's productivity?
8. Is it important to you for your work to be recognized for its contributing to environmental sustainability?
9. Does your facility currently run at maximum capacity?
10. Are there specific barriers that prevent the coop from achieving maximum capacity?
11. Do you think it is important for your work to be recognized for its contribution to environmental sustainability?
12. What are your thoughts regarding the potential for the cooperative to earn payment for environmental services, such as carbon credits?

Appendix 2: Questionnaire for Industry

1. Where is your plant located? Please include your address and zip code.
2. What types of products are produced using recycled materials in your plant?
3. What types of recyclable materials are used in the production of these products?
4. For each product, what other ingredients are used in the production of it?
5. For each product, what percentage of the entries comes from recyclable
6. For each product per kilogram of product, as is the consumption of energy and water in these production processes?
7. What energy sources are used by processes in your plant?
8. How much of your input is coming from the recyclable material recycling cooperatives?
9. What other sources provides your plant with recycled materials?
10. Do you notice any difficulty in obtaining materials recyclable? If so, what difficulties?
11. Do you notice any difficulty in the use of recyclable materials? If so, what difficulties?
12. How many workers have their factory? Please specify the posts as well.