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Contribution of cooperative sector recycling to greenhouse gas emissions reduction: A case study of Ribeirão Pires, Brazil

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ABSTRACT

Solid waste, including municipal waste and its management, is a major challenge for most cities and among the key contributors to climate change. 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 sale of recyclable resources. The present research attempts to measure the greenhouse gas emission reductions achieved by the recycling cooperative *Cooperpires*, as well as highlight its socio-economic benefits. Methods include participant observation, structured interviews, questionnaire application, and greenhouse gas accounting of recycling using a Clean Development Mechanism methodology. The results show that recycling cooperatives can achieve important energy savings and reductions in greenhouse gas emissions, and suggest there is an opportunity for *Cooperpires* and other similar recycling groups to participate in the carbon credit market. Based on these findings, the authors created a simple greenhouse gas accounting calculator for recyclers to estimate their emissions reductions.

1. Introduction

Throughout the last century, the world has experienced unprecedented urban population growth (Cohen, 2004; Satterthwaite, 2003; Population Reference Bureau, 2011), as well as the emergence of modern material culture and the trend towards disposability and increased consumption. Now, many commodities, and especially their packaging, are intended for disposal and not reuse (Lucas, 2002). The disposal of so much plastic, paper, cardboard, glass, metal, and organic materials compromises the environmental sustainability and public health of ever-growing urban environments and their surrounding sub- and peri-urban regions (Satterthwaite, 2003). According to Schor (2010), we have already reached the situation of ecological overshoot, with humans consuming far more than the available natural capacity to generate an ongoing supply of resources and to absorb the wastes generated.

A major challenge for most cities is the current rate of household waste generation, which often surpasses the financial and human resources of public authorities, the installed capacity of landfills, and the assimilation capacity of ecosystems to efficiently manage the waste (Karak et al., 2012). According to the fourth assessment report of the Intergovernmental Panel on Climate Change (Forster et al., 2007), waste and its management is one among seven key contributors to climate change.

2. Municipal solid waste and greenhouse gas emissions

Several processes directly and indirectly related to municipal solid waste (MSW) generation and management emit greenhouse gases (GHG; also commonly expressed in related literature as CO_2 equivalents [CO_2-eq.], an aggregate of gases that contribute to climate change). The principal climate-relevant GHG generated through solid waste management activities are methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) (Gentil et al., 2009; Machado et al., 2009). These emissions occur both upstream and downstream of the municipal solid waste management system (United States Environmental Protection Agency – US EPA, 2006). In the absence of recycling, upstream emissions occur mainly due to the acquisition and processing of virgin raw materials for

Abbreviations: card., cardboard; CDM, clean development mechanism; CO_2-eq., CO_2 equivalent; EF, emissions factor; DOC, degradable organic carbon; GJ, gigajoule; HDPE, high density polyethylene; k, decay rate for paper/card.; kW h, kilowatt hour; LDPE, low density polyethylene; MCF, methane (CH_4) correction factor; MRF, material recovery facility; MW h, megawatt hour; PET, polyethylene terephthalate; PP, polypropylene; PS, polystyrene; PSWM, Participatory Sustainable Waste Management project; PVC, polyvinyl chloride; SEC, specific electricity consumption; SFC, specific fuel consumption; t, metric tonne; UNFCCC, United Nations Framework Convention on Climate Change.

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product manufacturing, as they require higher fossil fuel energy consumption than recycled materials (Bogner et al., 2008; Diaz and Warith, 2006; Finnveden et al., 2005; Holmgren and Henning, 2004; Mohareb et al., 2008). Downstream emissions occur due to various waste management activities including and especially landfilling and incineration, but also composting and recycling. The majority of direct emissions are CH_4 and CO_2 associated with landfill disposal of biodegradable resources. There are also CO_2 and N_2O emissions associated with incineration, especially of plastics (Donovan et al., 2011; Morris, 2005; US EPA, 2006).

2.1. Recycling: environmental and socioeconomic benefits

A change in society's consumption patterns and a reduction in the amount of solid waste generated would significantly contribute to mitigate these burdens of MSW. A key premise to promote such transformed attitudes is the perception of waste as resource and to value it as such (Gutberlet, 2012a,b). Once solid waste is generated, recycling of plastic, paper, glass and metal materials is a better environmental practice in terms of GHG emissions reduction and energy conservation than landfilling, and in most cases is also preferable to incineration with or without energy recovery (Björklund and Finnveden, 2005; Chen and Lin, 2008; Mohareb et al., 2008; Morris, 2005), except when recycled plastics replace wood as opposed to virgin plastics (Astrup et al., 2009; Finnveden et al., 2005), and when energy recovered during incineration of paper/cardboard would replace fossil fuels (Björklund and Finnveden, 2005). Generally, however, the resource conservation benefits of replacing virgin resources with recycled materials tend to be greater than the energy production offsets of waste-to-energy technologies (Morris, 2005). Recycling also conserves capacity and extends the lifespan of existing landfills (Chester et al., 2008).

Despite the global necessity to create and implement sustainable waste management plans and legal frameworks which include policy support for recycling (Karak et al., 2012), many cities lack recycling programs and are struggling to extend basic waste management services to their entire populations (Barton et al., 2008; Decker et al., 2000; Forsyth, 2005; Shekdar, 2009; Uiterkamp et al., 2011; Wilson et al., 2006). Troschinetz and Mihelcic (2009) found that for 79% of the 23 low- and middle-income countries they studied, the lack of physical and human resources was a barrier to implementing municipal recycling schemes. In such cases, the selective collection of recyclable materials is often performed by the informal and cooperative sector recycling industry (Gutberlet, 2010; Gutberlet, 2012a,b; Forsyth, 2005; Noel, 2010; Schenck and Blaauw, 2011; Scheinberg et al., 2011; Sembiring and Nitivattananon, 2010). A growing number of studies (Chaturvedi, 2009; Fundação Nacional da Saúde – FUNASA, 2010; Henry et al., 2006; Lino & Ismail, 2011; Medina, 2000; Sembiring and Nitivattananon, 2010; Scheinberg et al., 2011; Talyan et al., 2008; Uiterkamp et al., 2011; Wilson et al., 2006; Wilson et al., 2009) demonstrate the resource mobilisation within this sector and the efficiency with which the informal and cooperative sector is able to provide this necessary environmental service in various cities across the world.

In addition to the environmental benefits of recycling, its socioeconomic benefits include employment opportunities in the reverse logistics industry, from collection to remanufacturing (Agarwal et al., 2005; Cointreau-Levine, 1994; Fehr and Santos, 2009;), which are an important source of income for the urban poor in low- and middle-income countries (Gutberlet 2011a,b, 2012a,b; Schenck and Blaauw, 2011; Noel, 2010).

For example, in the Metropolitan Region of São Paulo, Brazil, there are an estimated 20,000 recyclers, or *catadores*, in the informal/cooperative sector (FUNASA, 2010; Grimberg, 2007). The new National Policy on Solid Waste, law No. 12.305/2010 (*Política Nacional de Resíduos Sólidos*), demands the establishment of municipal selective collection systems, legislating the inclusion of recycling cooperatives and associations in the formal SWM system (Ministério do Trabalho e Emprego/Secretaria Nacional de Economia Solidária – MTE/SENAES, 2011). Further, *Programa Pró-Catador* is a national program which supports and promotes the organisation 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.

2.2. Triple bottom line sustainability: informal/cooperative sector recycling and the Clean Development Mechanism

One vehicle through which municipal governments in low- and middle-income countries can integrate environmental policies and initiatives with socioeconomic goals is the Clean Development Mechanism (CDM) (Barton et al., 2008; de Oliveira, 2009; World Bank, 2009), a carbon finance instrument offered by the United Nations Framework Convention on Climate Change (UNFCCC, 2012). Among the CDM methodologies there is one that accounts for GHG emissions reductions through resource recovery and recycling by informal and cooperative sector operations. CDM projects approved under this methodology have the potential to synchronise climate change mitigation, solid waste management, and socioeconomic development agendas (Chaturvedi, 2009; Reddy and Assenza, 2009; Rogger et al., 2011).

As of 2009, one of the main federal government programs in the Brazilian 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 Solid Waste Disposal), funded by the World Bank and the Government of Japan. The purpose of this program is to use the CDM as an effective tool in the implementation of economic, social and environmental programs towards sustainable development defined by the criteria set by Brazil's Interministerial Commission on Global Climate Change (Ministério da Ciência, Tecnologia e Inovação – MCTI, 2008). It is intended to contribute to social inclusion and empowerment of people relying on resource recovery and recycling as a livelihood (de Romani and Segala, 2007).

However, one of the major criticisms of the CDM is that it so far favours primarily large-scale private sector landfill gas projects such as methane capture-and-flare (destruction) and methane-to-energy initiatives (thermal/electrical energy generation) (Fenhann and Staun, 2010; Rogger et al., 2011; UNFCCC, 2010), which offer little immediate employment generation benefits in host countries (Olsen, 2007). For example, the landfill gas-to-energy project at the LARA landfill in Mauá, São Paulo, created only 6–10 long-term jobs (Det Norske Veritas, 2006). Meanwhile, a recycling cooperative offers an average of 36 positions to perform activities including collection, separation and sale of recyclable materials, and public awareness promotion (FUNASA, 2010). There are approximately thirty-three approved CDM landfill-gas projects in Brazil, and as yet, none that focuses on resource recovery and recycling, inclusive of the informal and cooperative sector. Social objectives such as poverty alleviation and employment generation tend to be under-represented, despite the apparent worldwide consensus to work towards the millennium development goals (of which poverty eradication is the number one), while corporate interests take priority in these so-called 'sustainable development' mechanisms (Forsyth, 2005; Gutberlet, 2011b; Gutberlet, 2012a,b; Rogger et al., 2011).

Those that carry out resources recovery and recycling activities within the informal and cooperative sector object to the proliferation of landfill-gas projects on the grounds that they bury and squander valuable resources when they should be recycled

(Gutberlet, 2011b, 2012a,b; SWACH, 2012). For CDM projects to achieve the triple-bottom-line of sustainability, a consensus of economic, social and environmental objectives must be achieved (Najam et al., 2003). Perhaps this is possible with the implementation of CDM projects focused on resource recovery and recycling, inclusive of the informal/cooperative sector.

This paper argues that such a consensus in municipal solid waste management may be achieved through the implementation of a cooperative sector CDM project focused on resource recovery and recycling. This argument is based on a recent case study of the Brazilian recycling cooperative *Cooperpires*, a participant in the Participatory Sustainable Waste Management (PSWM) partnership project with the University of Victoria, Canada, and the University of São Paulo, Brazil, which ran from 2005 to 2012 (Gutberlet, 2009). This research was conducted as part of the PSWM project in response to a request from *Cooperpires*' representatives.

Our study used the UNFCCC's CDM methodology for GHG emissions accounting of recycling and landfill diversion, complemented by a qualitative research methods. These qualitative methods provided further insight into *Cooperpires*' daily activities and challenges in their role as an environmental service provider. This mixed methods approach explored the available resources and the opportunity for the implementation of a cooperative sector CDM project focused on resource recovery and recycling.

3. Methods

3.1. Study area

The research is situated in the subtropical city of Ribeirão Pires, a municipality in the metropolitan region of São Paulo, Brazil (Fig. 1). The city has a total of 112,011 inhabitants, with a population density of approximately 1047 hab./km^2 (Secretaria de Saúde e Higiene de Ribeirão Pires, 2010). All of Ribeirão Pires' population receives waste collection service, which yielded 27,453 tonnes (0.67 kg/capita/day) in 2010, 98.5% of which were disposed of in the LARA sanitary landfill in the neighbouring municipality of Mauá (Secretaria de Saúde e Higiene de Ribeirão Pires, 2010).

Fig. 1. Map of the study area in Brazil. *Source*: Gutberet, 2012. The map shows Ribeirão Pires within the Metropolitan Region of São Paulo; the inset shows the location of São Paulo within Brazil.

3.2. Data collection

A participatory, mixed methods approach including participant observation, structured interviews, and questionnaires was employed. Data collection took place between November 2010 and February 2011, along the selective collection routes through Ribeirão Pires' city centre and surrounding neighbourhoods, and at the *Cooperpires* material recovery facility (MRF). Participant observation and interview methods assessed the flow and processing of recyclable resources including paper/cardboard, glass, metals and plastics, and the efficiency, organisation, and physical and human resources of the cooperative. These data informed the GHG accounting method, and it provided supplementary qualitative data that filled in some knowledge gaps in terms of assessing triple bottom line sustainability. Questionnaires were applied to ask reverse logistics companies about the processing and end-use of the materials they purchase from the recycling cooperative.

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, aluminium, and steel. Structured interviews explored recyclers' opinions about their contribution as environmental service providers, 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 possibility 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 quantitative data was collected through literature review, and personal communications. This data included CO_2 emissions factors for electricity generation, and specific energy consumption for recyclable resources including high density polyethylene (HDPE)/polypropylene (PP), low density polyethylene (LDPE), and polyethylene terephthalate (PET)/polystyrene (PS) plastics, paper/cardboard, glass, aluminium, and steel. This data is based on the literature and default values provided in the CDM methodology (Tables 1 and 2). Material flow data from sales ledgers for 2010, provided by the *Cooperpires* cooperative, accounting all quantities (Table 2), unit prices, and receipts for each type of recyclable resources sold to reverse logistics companies. Data from the LARA landfill, obtained through local news media, the Ribeirão Pires government website, and UNFCCC CDM project literature. Data relating to regular municipal solid waste collection and

Table 1
Categorisation 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

Table 2
Specific electricity consumption $SEC_{BL,i}$ and SEC_{rec} and specific fuel consumption $SFC_{BL,i}$ shown as MW h/tonne; quantity (tonnes) of recycled resources $Q_{i,y}$ and adjustment factor L_iL_i for production with virgin vs. recycled resources.

Resource type (index)	Virgin resources		Recycled resources	Tonnes recycled	Adjustment factor
	$SFC_{BL,i}$	$SEC_{BL,i}$	SEC_{rec}	$Q_{i,y}$	L_i
HDPE/PP[a](1)	4.17	0.83	0.83	17.5	0.75
LDPE[a](2)	4.17	1.67	0.83	18	0.75
PET/PS[a](3)	4.17	1.11	0.83	10	0.75
Paper/card.[b](4)		4.98	1.47	189	0.82
Glass[‡](5)		4.83	4.19	25.5	0.88–1.0[c]
Aluminium[b](6)		17.6	0.7	1.5	0.9–1.0[c]
Steel[b](7)		6.84	1.78	24.5	0.84

[a] $SEC_{BL,i}$ and SEC_{rec} values for plastics are default values as per the CDM methodology (UNFCCC, 2011a).
[b] $SEC_{BL,i}$ and SEC_{rec} values for these resources follow Pimenteira et al. (2004) and Gomes and Nóbrega (2005); L_i values for these resources follow Rigamonti et al. (2009), except for paper/cardboard (Merrild et al., 2009), and aluminium (Damgaard et al., 2009).
[c] Adjustment factor can be 1.0 for glass and aluminium because both resources can be completely recycled (closed loop) when producing the same product (e.g., used glass bottles/aluminium cans re-manufactured into new glass bottles/aluminium cans [ICF Consulting, 2005]).

management in Ribeirão Pires. Information about the wider cooperative recycling community and its stakeholders gathered from PSWM project literature.

3.3. Greenhouse gas accounting

The GHG emission reductions achieved through the recycling of a select portion of the MSW generated by Ribeirão Pires were measured using the CDM GHG accounting methods – AMS III-AJ: Resource recovery and recycling of material from solid waste (UNFCCC, 2008, 2011a, 2011b), and the methodological tool to determine methane emissions avoided from disposal of wastes at a waste disposal site (UNFCCC, 2011c). In the CDM methodology, GHG emissions reductions ER_y were calculated by subtracting the emissions that occur as a result of recycling and landfill diversion activities PE_y - LE_y from the emissions that would have occurred in the absence of those activities BE_y then adding the CH_4 emissions avoided from prevention of landfilling paper and cardboard $BE_{CH4,SWDS,y}$ as given in Eq. (1).

$$ER_y = (BE_y - PE_y - LE_y) + BE_{CH4,SWDS,y} \quad (1)$$

where ER_y, emission reductions in year y (tCO_2-eq); BE_y, Baseline emissions in year y (tCO_2-eq) Eqs. (2) and (3); PE_y, Project emissions in year y (tCO_2-eq), Eq. (4); $LE_yLE_{EC,y}$, leakage emissions in year y (tCO_2-eq), Eq. (5); $BE_{CH4,SWDS,y}$, CH_4 emissions avoided from prevention of landfilling paper and cardboard. (tCO_2-eq./ 2010), Eq. (6).

The assumption of the AMS III-AJ: Recovery and recycling of material from solid waste methodology[1] is that in the Baseline Scenario (Fig. 2), in which no recycling happens, approximately 286 tonnes of paper/cardboard, plastics, glass and metal waste generated by the residents and businesses of Ribeirão Pires would be disposed at the LARA sanitary landfill. The Baseline Scenario also assumes that because these resources were not recycled back into the manufacturing product chain, 286 tonnes of virgin resources were instead used in product fabrication. In our Project Scenario (Fig. 3), we assume that 286 tonnes of recyclable resources were, in fact, recycled into new products.

3.3.1. Calculating BEy and PEy: baseline and project CO2-eq. emissions

The CDM methodology, AMS III-AJ: Recovery and recycling of material from solid waste (UNFCCC, 2011a), currently accounts only for specific plastic types, namely HDPE, LDPE, and PET, and for paper/cardboard. We used this method, as is, to account for these specific materials, and then used a modified version to assess the approximate emissions from all other types of recyclable resources. To account for the maximum number of plastic varieties, 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 et al., 2009 (Table 1).

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, Eq. (2) is used. A modified version of the method, represented in Eq. (3), was used to calculate Baseline and Project emissions associated with only hydroelectricity consumption in the production of paper products, glass, aluminium and steel from virgin and recycled resources (see Table 2).

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

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

where BE_y, Baseline emissions per year y (tonnes CO_2/y); I, Indices for resource type (Table 2); $Q_{i,y}$, Quantity of resource type i recycled per year y. (tonnes/year). Data from Cooperpires' sales ledgers (Table 2); 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 (Table 2); $SEC_{BL,i}$, Specific electricity consumption for the production of virgin resource type i (MW h/tonne) (Table 2); $EF_{el,y}$, emission factor for the grid electricity generation. Use 0.22–0.38 (after Dones et al., 2004; Fruergaard et al., 2009); $SFC_{BL,i}$, Specific fuel consumption for the production of virgin resource plastic type i. (GJ/tonne) (Table 2); $EF_{FF,CO2}$, CO_2 emission factor for fossil fuel (dry natural gas; tCO_2/GJ). Use 0.056 (Pipatti et al., 2006)

We calculated project activity emissions associated with energy consumption for the production of goods from recycled resources using Eq. (4):

$$PE_y = \sum_i (Q_{i,y} * SEC_{rec} * EF_{el,y}) \quad (4)$$

where SEC_{rec}, specific electricity consumption for recycled resource type i (MW h/tonne) (Table 2); $EF_{el,y}$, emission factor for the grid electricity generation. Use 0.22–0.38 (after Dones et al., 2004; Fruergaard et al., 2009).

3.3.1.1. Specific energy consumption in virgin versus recycled resource production. Baseline emissions BE_y for production using virgin

[1] Emissions associated with transportation under the Project Scenario are considered as equivalent to the corresponding emissions under the Baseline Scenario and therefore ignored in the methodology, as are emissions associated with the extraction/processing of virgin resources.

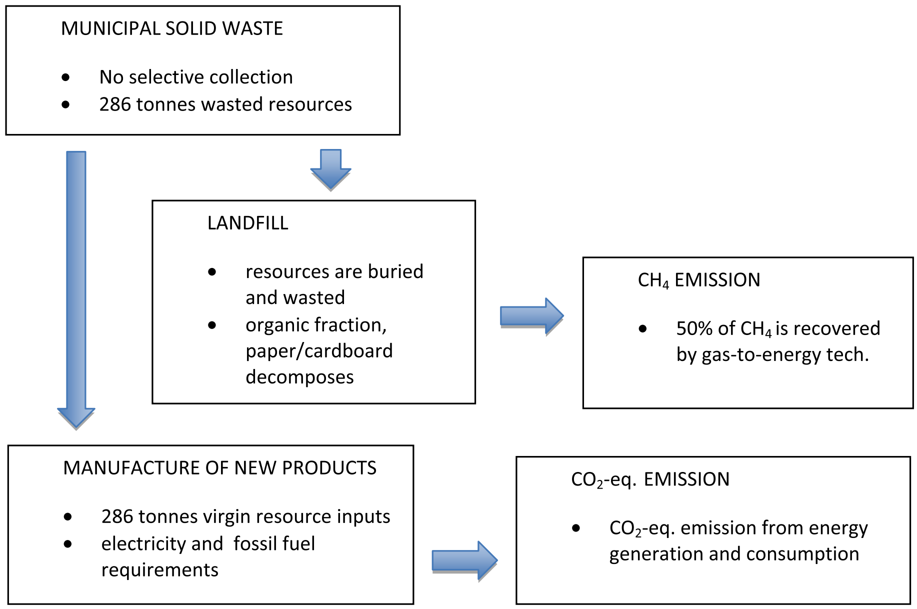

Fig. 2. Baseline scenario the diagram shows the system boundary of the processes under study in the absence of recycling.

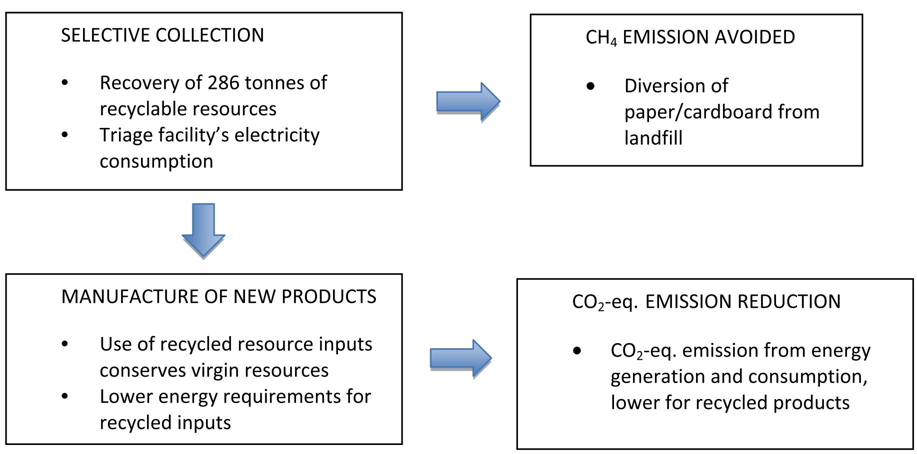

Fig. 3. Project scenario: the diagram shows the system boundary of the processes under study when recycling occurs.

resource inputs, and project activity emissions PE_y for production using recycled resource inputs, were calculated in Eqs. (2)–(4). The following specific energy consumption values for virgin resources, $SEC_{BL,i}$ and $SFC_{BL,i}$, and for recycled resources, SEC_{rec}, were sourced from Brazilian studies by Pimenteira et al. (2004), Gomes and Nóbrega (2005), and Lino and Ismail (2011), for paper/cardboard, glass, and metals, while the CDM method default values of these variables were used for all plastic types (Table 2).

3.3.1.2. CO_2 emission factor of hydropower in Brazil and Energy conversion efficiency. Given Brazil's high dependence on hydroelectricity, this study assumes that hydroelectricity is supplying the energy input for all recycling processes within the Project system boundary, and that it has an emissions factor of 0.2–0.34 kg CO_2-eq./kW h of emissions (Dones et al., 2004; Fruergaard et al., 2009). The emission factor for grid electricity generation $EF_{el,y}$ ($EF_{el,y}$ and $EF_{EL,m,y}$) was calculated using option A2 of the CDM methodological instrument, *Tool to calculation emission factor for an electricity system* (UNFCCC, 2011b), to calculate the emission factor of 0.22–0.38 tonnes CO_2-eq./kW h.

3.3.2. Calculating $LE_{EC,y}$: 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* (UNFCCC, 2008), with the following Eq. (5):

$$LE_{EC,y} = \sum_i EC_{LE,l,y} * EF_{EL,l,y} * (1 + TDL_{l,y}) \quad (5)$$

where $LE_{EC,y}$, leakage emissions from electricity consumption in year y (tCO_2/y); $EC_{LE,l,y}$, net increase in electricity consumption of source l in year y as a result of leakage (MW h/year); use 0.00456 (AES Electropaulo, 2011; Tyco Electronics Corporation, 2005); $EF_{EL,l,y}$, Emission factor for electricity generation for source l in year y (tCO_2/MW h); use 0.22 (Dones et al., 2004; Fruergaard et al., 2009); $TDL_{l,y}$, 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* MRF.

To calculate $EC_{LE,l,y}$, we assumed a leakage current of 5.0 milliamperes and a tension of 30 kilovolts (AES Electropaulo, 2011; Tyco Electronics Corporation, 2005) to give the following conversion: 5.0 mA × 30 kV = 0.005 A × 30,000 V = 0.000150 MW/12 h = 0.0000125 MW h × 365 = 0.00456 MW h/year.

3.3.3. Calculating $BE_{CH4,SWDS,y}$: avoided methane (CH_4) emissions

The GHG emissions from landfilled paper and cardboard are calculated using the methodological tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (UNFCCC, 2011c). Eq. (6) calculates baseline emissions of CH_4 from waste that, in the absence of the project activity, would be disposed of at the LARA landfill in Mauá, which currently receives approximately 3000 tonnes of MSW per day (Mayara, 2013).

LARA is a sanitary landfill: it 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. It utilises methane-to-energy technology, assumed to capture 50% of landfill gas, and has been registered as a CDM Landfill Gas to Energy Project since 2006 (Det Norske Veritas, 2006). According to the Koeppen climate classification, Mauá has a Cwa-humid subtropical climate, with a mean annual temperature of 19.6 °C and a mean annual precipitation of 1413.6 mm (Centro de Pesquisas Meteorologicas e Climáticas Aplicadas a Agricultura – CEPAGRI, 2012).

All variables in Eq. (6) were given the default values provided in the methodology. To accommodate for uncertainties, the equation was run for eight different baseline scenarios based on the ranges of default values given in the methodology for the following three variables: the methane correction factor (*MCF*); the condition of collected paper/cardboard, affecting the fraction of organic carbon (DOC_j); and the climate-dependent decay rate (k_j).

$$BE_{CH4,SWDS,y} = \varphi * (1-f) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_f * MCF * \sum_{x=1}^{y}\sum_{j} W_{j,x} * DOC_j * e^{-k*(y-x)} * (1 - e^{-k_j}) \tag{6}$$

where $BE_{CH4,SWDS,y}$, CH_4 emissions avoided from prevention of landfilling paper and cardboard. (tCO_2-eq./2010); φ, Correction factor for model uncertainties. Use 0.9; GWP_{CH4}, Global warming potential of CH_4 for the first commitment period; use 21 (default data as per the methodology); *f*, Fraction of CH_4 captured at the landfill. Use 0.5; *OX*, oxidation factor, reflecting the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste; use 0.1; *F*, fraction of CH_4 from landfill that is oxidised in the soil of covering material (volume fraction); use 0.1; DOC_f, fraction of degradable organic carbon that can decompose. Use 0.5; *MCF*, CH_4 correction factor; use 1.0 (anaerobic scenario) on 0.5 (semi-aerobic scenario); $W_{j,x}$, Amount of paper/cardboard prevented from disposal in landfill in 2010 (tonnes). Use 189.0 (Cooperpires sales ledgers); DOC_j, fraction of degradable organic carbon by weight (tonnes) of paper/cardboard. Use 0.44 (86.13 tonnes dry waste) and 0.4 (75.6 tonnes wet waste); k_j, decay rate for waste type j; use 0.06 (wet temperate climate, with a mean annual temperature of <20 °C) and 0.07 (wet tropical climate, with a mean annual temperature of >20 °C, and a mean annual precipitation of >1000 mm) (Pipatti et al., 2006); *j*, waste type: paper/cardboard; *y*, year during the crediting period: 2011; *x*, year for which methane emissions are calculated: 2010.

4. Results

4.1. Energy conservation

According to *Cooperpires*' accounts, the daily operations of the cooperative's material recovery facility consume an average of 197 kW h/month, or 8.2 kW h/tonne, to separate, press and bale about 24 tonnes/month of recyclable resources in 2010. This electrical energy consumption rate follows Bovea and Powell (2006), who consider the rate of consumption for a Spanish MRF/transfer station to be around 7.2 kW h/tonne.

Meanwhile, the remanufacturing of 286 tonnes of the recyclable resources sold by the cooperative conserve 78.75% of the electrical energy that is expected to be consumed by the use of virgin resources, saving an average of 5.67 MW h (13 GJ)/tonne (Table 3).

The results for steel, plastics, and aluminium are in line with the findings of Rigamonti et al. (2009), whose Life Cycle Assessment of selective collection and recycling within a formal MSW management system in Italy show similar energy savings of 81.2%, 91.4%, and 93.5%, respectively. However, the findings diverge with respect to glass and paper, as Rigamonti et al. show an energy saving of 36.1% and 99.4%, respectively.

4.2. Greenhouse gas emission reductions

The results of the CDM GHG accounting method show that *Cooperpires*' recycling activities contribute to an emissions reduction of 1443–2720 tCO_2-eq.; approximately 166–276 tCO_2-eq. are avoided through recycling, and about 1277–2444 tCO_2-eq. through landfill diversion of paper/cardboard. Depending on the baseline scenario used in Eq. (2) for calculating methane emissions (Table 4), landfill diversion of 189 tonnes of paper/cardboard accounts for up to 90% of the total CO_2-eq. emissions reduction that results from *Cooperpires*' recycling activities. The GHG emissions reduction per tonne of paper/cardboard diverted from the landfill is 6.75 tCO_2-eq. This can be compared the emissions reductions for Northern Europe cited by Merrild et al., 2009, of 3.9–4.4 tCO_2-eq. avoided per tonne of recycled paper.

GHG emissions reductions per tonne of each recycled resource type replacing virgin resources in manufacturing (Table 5) are in alignment with recent literature, in which the findings of studies using life cycle analyses of recycling within formal MSW management systems show that using recycled materials instead of raw materials yielded GHG emissions reductions of 0.45–1.83 tCO_2-eq.

Table 3
Electricity consumed by virgin and recycled resources in production, and electricity conserved by using recycled resources, per tonne (t) of each resource type collected and sold by *Cooperprires* in 2010.

Resource type (*i*)	Quantity (tonnes)	Virgin resources	Recycled resources	Electricity conserved	
		MW h/t	MW h/t	MW h/t	% Saved
HDPE/PP (1)	17.5	5.0	0.83	4.17	83.4
LDPE (2)	18.0	5.84	0.83	5.0	85.6
PET/PS (3)	10	5.28	0.83	4.45	84.3
Paper/ cardboard (4)	189.0	4.98	1.47	3.5	70.3
Glass (5)	25.5	4.83	4.19	0.6	12.4
Aluminium (6)	1.5	17.6	0.7	17.0	96.6
Steel (7)	24.5	6.84	1.78	5.0	73.1
TOTAL	286	7.2	1.52	5.67	78.75

Table 4
Baseline Methane (CH_4) emissions avoided through landfill diversion of paper/cardboard collected and sold by *Cooperpires*.

Baseline scenario				CH_4 emissions avoided
1	Anaerobic	Dry	Temperate	2443.8 tCO_2-eq.
2	Anaerobic	Dry	Tropical	2808.8 tCO_2-eq.
3	Anaerobic	Wet	Temperate	2221.6 tCO_2-eq.
4	Anaerobic	Wet	Tropical	2553.4 tCO_2-eq.
5	Semi-aerobic	Dry	Temperate	1221.9 tCO_2-eq.
6	Semi-aerobic	Dry	Tropical	1404.4 tCO_2-eq.
7	Semi-aerobic	Wet	Temperate	1110.8 tCO_2-eq.
8	Semi-aerobic	Wet	Tropical	1276.7 tCO_2-eq.

per tonne of plastics and 0.57–0.78 tCO_2-eq. per tonne of paper products (Chen and Lin, 2008; Friedrich and Trois, 2013); 0.03–0.5 tCO_2-eq. per tonne of glass (Chen and Lin, 2008; Friedrich and Trois, 2013; Larsen et al., 2009); 4.53–19.3 tCO_2-eq. per tonne of aluminium (Chen and Lin, 2008; Damgaard et al., 2009; Friedrich and Trois, in press); and, 0.6–2.6 tCO_2-eq. per tonne of steel (Damgaard et al., 2009; Friedrich and Trois, 2013).

The average GHG emissions reduction achieved through substitution of recycled resources for virgin resources is 0.58–0.96 tCO_2-eq. per tonne of recycled material (Table 5). This is on par with emissions reductions achieved through landfill gas capture/flaring or waste-to-energy, as demonstrated by Lombardi et al., 2006. The authors show that the destruction of landfill gas through capture/flaring reduces GHG emissions by 0.788 tCO_2-eq.per tonne of MSW. Similarly, energy recovery through waste-to-energy reduces GHG emissions by 0.966 tCO_2-eq.per tonne of MSW.

Comparison of the present results with the literature cited above should consider the fact that the life cycle methods used by these other authors account for a wider range of parameters, including transportation and non-energy GHG emissions, than the CDM method allows.

4.3. Selective collection and separation

Cooperpires recycling cooperative has performed selective collection of recyclable materials from households and businesses within Ribeirão Pires since 2004. At the time of data collection, *Cooperpires* was equipped with two collection trucks, 6 push-carts, a city centre transfer station, and a MRF where collected materials were separated and processed for sale. Collected recyclables were manually transferred from truck to a stationary triage table, where they were manually separated before being pressed in a hydraulic press which crushes and bales materials into 150 kg bales. The bales were then transported by electric forklift to be weighed and stocked (Filipe, *Cooperpires* member, interview, 2010).

Door-to-door selective collection was accomplished using a truck in residential areas and on foot with push-carts throughout the city centre. *Cooperpires*' services five neighbourhoods and the city centre, covering about 400 km of route, which included the MRF and transfer station. Although the household participation rate is unknown, one Cooperpires member estimated that their weekly service was available to about 8% of the Ribeirão Pires' population (Sergio, *Cooperpires* member, interview, 2010). Since 2004, *Cooperpires*' selective collection yield increased from 10 tonnes to approximately 30 tonnes per month, collecting 350 tonnes of recyclable materials in 2010. After 17% of collected materials were discarded and disposed of in the local landfill, the cooperative was able to sell to reverse logistics companies almost 290 tonnes of recyclables, or 0.62% of total municipal solid waste generated by the population of Ribeirão Pires.

5. Discussion

Cooperpires is an example of a recycling cooperative working in partnership with multiple stakeholders towards triple bottom line sustainability and an integrated municipal solid waste management service. Our study shows that a significant reduction in GHG emissions can be achieved through cooperative recycling. Although landfill gas capture/flaring and waste-to-energy technologies achieve similar GHG emissions reductions, neither offer the socioeconomic benefits of recycling as it is presented in this study.

Cooperpires' environmental contribution can be heightened through increased public participation in source separation of recyclables, a larger staff of recyclers within the cooperative, and additional equipment. The GHG emissions reductions offer an opportunity for greater socioeconomic and environmental benefits if *Cooperpires* is supported in gaining approval as a CDM project or similar initiative that recognises and remunerates the environmental service performed by these workers.

5.1. CDM project opportunity for recycling cooperatives

The environmental, social and economic imperatives for the expansion of selective collection services, as well as the legal framework, policy support, and financial and physical resources already invested by federal and municipal governments have created the potential for *Cooperpires* and similarly well-organised and equipped recycling cooperatives to engage in carbon credit trading as a CDM project.

A sustainable CDM project must have poverty alleviation and socioeconomic exclusion as part of its mandate. Municipal waste management and climate change mitigation policies and legislation must be designed and enacted in a way that safeguards and expands existing jobs for informal and cooperative sector recyclers, as well as supports the formation of new cooperatives, and preferential awarding of contracts to this sector for the provision and administration of selective collection programs. The people who make their living from resource recovery and recycling waste are

Table 5
Baseline and project greenhouse gas emissions (tonnes CO_2-eq.), and the emissions reductions (tonnes CO_2-eq.) achieved in 2010 by replacing virgin resources with recycled resources, *i* (collected and sold by *Cooperpires*), in the fabrication of new products.

Resource type (*i*)	Baseline emissions (tonnes CO_2-eq.)	Project emissions (tonnes CO_2-eq.)	Emissions reductions (tonnes CO_2-eq.)	Emissions reductions (tonnes CO_2-eq.) per tonne of *i* recycled
HDPE/PP (1)	13.4–15.2	3.2–5.5	9.7–10.2	0.55–0.6
LDPE (2)	16.4–20	3.3–5.7	13 .1–14.3	0.73–0.8
PET /PS (3)	8.1–9.5	1.8–3.2	6.3	0.63
Paper/cardboard (4)	170–293.8	61.1–105.8	108.9–188	0.57–1.0
Glass (5)	24–41.2	23.5–40.6	0.5–0.6	0.02
Aluminium (6)	6–10.2	0. 2–0.4	5.8–9.8	3.86–6.5
Steel (7)	31–53.5	9.6–16.6	21.4–37	0.87–1.5
Total			165.7–276.4	0.58–0.96

GREENHOUSE GAS EMISSIONS REDUCTION CALCULATOR FOR RECYCLING COOPERATIVES								
		Baseline emissions		– Project emissions		= Emissions reduction		
Resource	Quantity (tonnes)	Virgin resources Emissions/ tonne (et)	Baseline emissions	Recycled resources Emissions/ tonne	Project emissions	Emissions reduction*		
HDPE/PP	0	0.767	0.000	0.183	0.000	-0.001		
LDPE	0	0.906	0.000	0.183	0.000	-0.001		
PET/PS	0	0.813	0.000	0.183	0.000	-0.001		
Paper/card.	0	0.898	0.000	0.323	0.000	-0.001		
Glass	0	0.935	0.000	0.922	0.000	-0.001		
Aluminum	0	3.872	0.000	0.154	0.000	-0.001		
Steel	0	1.264	0.000	0.392	0.000	-0.001		
			0.000		0.000	-0.001		
Total CO_2-eq. emissions avoided by the substitution of virgin resources by recycled resources							-0.001	t CO_2-eq./year
Paper/card.	0	5.877	0.000					
Total CH_4 emissions avoided by the landfill diversion of paper/cardboard							0.000	t CO_2-eq./year
				TOTAL CO_2-eq. emissions reduction			-0.001	t CO_2-eq./year
* includes subtraction of Leakage emissions (LE) from electricity consumption = 0.001 t CO_2-eq./year								

Fig. 4. Greenhouse gas emissions reduction calculator for recycling cooperatives. The illustration shows the model of a simple greenhouse gas emissions reduction calculator for use by recycling cooperatives to estimate their yearly CO_2-eq. emissions reduction.

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 and Coad, 2007).

Financial and physical resources and government support are of critical importance to these cooperatives and selective collection programs (FUNASA, 2010; Gutberlet, 2010). 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. Considering the 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 federal and municipal governments to the development of recycling programs, a synergy of climate and waste management policies could create the opportunity for recycling cooperatives to become registered CDM projects and participate in the carbon credit market. To this end, we created a GHG emissions reduction calculator, using the formulas and default data from CDM methodologies and the empirical data from *Cooperpires* as references. This methodology will allow other recycling cooperatives to estimate their own emissions reductions.

The calculator provides the *Quantity (tonnes)* column where recycling cooperatives can enter their yearly yields, in tonnes, of each type of recyclable material (Fig. 4). The calculator produces the total CO_2-eq. emissions avoided by the substitution of virgin resources by recycled resources as well as the total CH_4 emissions (expressed as CO_2-eq.) avoided by the landfill diversion of paper/cardboard.

6. Conclusion

Informal/cooperative sector recycling is capable of achieving GHG emissions reductions similar to those achieved by recycling and landfill gas capture/flaring within formal MSW management systems. *Cooperpires*' selective collection and recycling services, and thereby, its contribution to GHG emissions reduction could be increased through an expansion of its service to a greater percentage of the population of Ribeirão Pires, a larger staff of recyclers within the cooperative, and additional equipment. As a CDM project, the carbon credits that *Cooperpires* could earn for its GHG emissions reductions would facilitate this expansion, as well as enhance the socioeconomic benefits for its workers.

Carbon crediting is an important instrument to visualise resource recovery and to value the socioeconomic and environmental benefits of recycling. By recognising the work of selective waste collection and separation performed by informal/cooperative recyclers as a Clean Development Mechanism (Instituto de Pesquisa Econômica Aplicada – IPEA & IBGE, 2004; United Nations, 2011), Brazil's CDM commitment can fully meet the criteria for sustainable development. However, the national and supranational bodies governing carbon finance and waste management must do more to encourage projects focused on resource recovery and recycling inclusive of the informal and cooperative sector, instead of funding landfills and waste to energy schemes. Such environmental and socioeconomic outcomes would be in line with the UN Millennium Development Goals, which focus development efforts on poverty alleviation, equitable and inclusive economic growth (United Nations, 2011).

Government support for informal/cooperative sector recycling and the co-management of recyclable resources is crucial to the realisation of 'triple bottom line' sustainable, inclusive, integrated municipal solid waste management service in Ribeirão Pires and across the Metropolitan Region of São Paulo.

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References

AES Eletropaulo, 2011. Sistema de Tarifação. AES Eletropaulo. <http://www.aeseletropaulo.com.br/clientes/ClientesCorporativos/informacoes/Paginas/SistemadeTarifacao.aspx> (accessed 27.02.12).

Agarwal, A., Singhmar, A., Kulshrestha, M., Mittal, A.K., 2005. Municipal solid waste recycling and associated markets in Delhi, India. Resources, Conservation & Recycling 44, 73–90. http://dx.doi.org/10.1016/j.resconrec.2004.09.007.
Astrup, T., Fruergaard, T., Christensen, T.H., 2009. Recycling of plastics: accounting of greenhouse gases and global warming contributions. Waste Management & Research 27 (8), 763–772.
Barton, J.R., Issaias, I., Stentiford, E.I., 2008. Carbon – making the right choice for waste management in developing countries. Waste Management 28, 690–698.
Björklund, A., Finnveden, G., 2005. Recycling revisited – life cycle comparisons of global warming impact and total energy use of waste management strategies. Resources, Conservation and Recycling 44, 309–317.
Bogner, J., Pipatti, R., Hasimoto, S., Diaz, C., Mareckova, K., Diaz, L., et al., 2008. Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). Waste Management 26, 11–32.
Bovea, M.D., Powell, J.C., 2006. Alternative scenarios to meet the demands of sustainable waste management. Journal of Environmental Management 79 (2), 115–132.
Centro de Pesquisas Meteorologicas e Climáticas Aplicadas a Agricultura – CEPAGRI, 2012. Clima dos Municípios Paulistas. A classificação climática de Koeppen Para o estado de São Paulo. <http://www.cpa.unicamp.br/outras-informacoes/clima_muni_333.html> (accessed 22.02.13).
Chaturvedi, B., 2009. Cooling Agents: An analysis of Greenhouse Gas Mitigation by the Informal Recycling Sector of India. CHINTAN Environmental Research and Action Group, New Delhi.
Chen, T.-C., Lin, C.-F., 2008. Greenhouse gases emissions from waste management practices using life cycle inventory model. Journal of Hazardous Materials 155, 23–31.
Chester, M., Martin, E., Sathaye, N., 2008. Energy, greenhouse gas, and cost reductions for municipal recycling systems. Environmental Science & Technology 42, 2142–2149.
Cohen, B., 2004. Urban growth in developing countries: a review of current trends and a caution regarding existing forecasts. World Development 32 (1), 23–51. http://dx.doi.org/10.1016/j.worlddev.2003.04.008.
Cointreau-Levine, S., 1994. Private Sector Participation in Municipal Solid Waste Services in Developing Countries, vol. 1. The Formal Sector. World Bank Urban Management Programme, Washington, DC.
Damgaard, A., Larsen, A.W., Christensen, T.H., 2009. Recycling of metals: accounting of greenhouse gases and global warming contributions. Waste Management & Research 27, 773–780.
de Oliveira, J.A.P., 2009. The implementation of climate change related policies at the subnational level: an analysis of three countries. Habitat International 33, 253–259.
Romani, A. P. de & Segala, K., 2007. Mecanismo de desenvolvimento limpo aplicado a resíduos sólidos. Agregando valor social e ambiental. Rio de Instituto Brasileiro de Administração Municipal (IBAM), Janeiro.
Decker, E.H., Elliott, S., Smith, F.A., Blake, D.R., Rowland, F.S., 2000. Energy and material flow through the urban ecosystem. Annual Review of Energy and the Environment 25 (1), 685–740.
Det Norske Veritas, 2006. Validation Report: Landfill Gas to Energy Project at LARA Landfill, Mauá, Brazil. Report No. 2004-1061. <http://www.mct.gov.br/index.php/content/view/66187.html> (retrieved 12.02.12).
Diaz, R., Warith, M., 2006. Life-cycle assessment of municipal solid wastes: development of the WASTED model. Waste Management 26, 886–901.
Dones, R., Heck, T., Hirschberg, S., 2004. Greenhouse gas emissions from energy systems: comparison and overview. Encyclopaedia of Energy 3, 77–95.
Donovan, S.M., Pan, Jilang, Bateson, T., Gronow, J.R., Voulvoulis, N., 2011. Gas emissions from biodegradable waste in United Kingdom landfills. Waste management & Research: The Journal of the International Solid Wastes and Public Cleansing Association, ISWA 29 (1), 69–76.
Fehr, M., Santos, F.C., 2009. Landfill diversion: moving from sanitary to economic targets. Cities 26, 280–286.
Fenhann, J., Staun, F., 2010. An analysis of key issues in the clean development mechanism based on the UNEP Risoe clean development mechanism pipeline. Carbon Management 1 (1), 56–77.
Filipe, 2010 Cooperpires member. Interview. 26 Feb. 2010.
Finnveden, G., Johansson, J., Lind, P., Moberg, A., 2005. Life cycle assessment of energy from solid waste – Part 1: general methodology and results. Journal of Cleaner Production 3, 213–229.
Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M., Van Dorland, R., 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
Forsyth, T., 2005. Building deliberative public–private partnerships for waste management in Asia. Science 36 (4), 429–439.
Friedrich, E., Trois, C., 2013. GHG emission factors developed for the recycling and composting of municipal waste in South African municipalities. Waste Management 33 (11), 2520–2531.
Fruergaard, T., Astrup, T., Ekvall, T., 2009. Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions. Waste Management & Research 27 (8), 724–738.
Fundação Nacional da Saúde – FUNASA, 2010. Programas municipais de coleta seletiva de lixo como fator de sustentabilidade dos sistemas públicos de saneamento ambiental na região metropolitana de São Paulo. Brasília: Ministério da Saúde. <http://www.funasa.gov.br/internet/Bibli_estPesq.asp> (retrieved 26.02.12).
Gentil, E., Christensen, T.H., Aoustin, E., 2009. Greenhouse gas accounting and waste management. Waste Management & Research 27 (8), 696–706.
Gomes, H.P., Nóbrega, C.C., 2005. Economic viability study of a separate household waste collection in a developing country. Journal of Material Cycles and Waste Management 7, 116–123.
Gonzenbach, B., Coad, A., 2007. Solid waste management and the Millennium Development Goals: links that inspire action. In: CWG Publication Series No. 3 (Ed.), Collaborative Working Group on Solid Waste Management in Low- and Middle-Income Countries.
Grimberg, E., 2007. Coleta seletiva com inclusão dos catadores: Fórum Lixo e Cidadania da Cidade de São Paulo. Experiência e desafios. Revistas Pólis, 49. <http://www.polis.org.br/publicacoes_interno.asp?codigo=257> (accessed 26.02.12).
Gutberlet, J., 2009. Solidarity economy and recycling co-ops in Sao Paulo: micro-credit to alleviate poverty. Development in Practice 19 (6), 737–751. http://dx.doi.org/10.1080/09614520903026892.
Gutberlet, J., 2010. Waste, poverty and recycling. Waste Management 30 (2), 171–173. http://dx.doi.org/10.1016/j.wasman.2009.11.006.
Gutberlet, J., 2011a. Waste to Energy, Wasting Resources and Livelihoods. Integrated Waste Management, vol. 1. <http://www.intechopen.com/source/pdfs/17438/InTech-Waste_to_energy_wasting_resources_and_livelihoods.pdf> (accessed 20.02.12).
Gutberlet, J., 2011b. The social cost of incinerating solid waste: Recovering energy in detriment to sustainability (O custo social da incineração de resíduos sólidos: Recuperação de energia em detrimento da sustentabilidade). Revista Geográfica de América Central, Número Especial XIII EGAL, 2011- Costa Rica, Vol. 2 (47E), pp. 1–16.
Gutberlet, J., 2012a. Informal and cooperative recycling as a poverty eradication strategy. Geography Compass 6(1), 19–34. <http://onlinelibrary.wiley.com/doi/10.1111/j.1749-8198.2011.00468.x/full> (retrieved 26.02.12).
Gutberlet, J., 2012a. Map of the study area in Brazil [map]. 1:787,400. In: Informal and Cooperative Recycling as a Poverty Eradication Strategy. Geography Compass 6(1), 20. <http://onlinelibrary.wiley.com/doi/10.1111/j.1749-8198.2011.00468.x/full> (retrieved 26.02.12).
Henry, R.K., Yongsheng, Z., Jun, D., 2006. Municipal solid waste management challenges in developing countries – Kenyan case study. Waste Management 26, 92–100. http://dx.doi.org/10.1016/j.wasman.2005.03.007.
Holmgren, K., Henning, D., 2004. Comparison between material and energy recovery of municipal waste from an energy perspective: a study of two Swedish municipalities. Resources, Conservation and Recycling 43, 51–73. http://dx.doi.org/10.1016/j.resconrec.2004.05.001.
Hopewell, J., Dvorak, R., Kosior, E., 2009. Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society B 364, 2115–2126.
ICF Consulting, 2005. Determination of the Impact of Waste Management Activities on Greenhouse Gas Emission: 2005 Update. Final Report. <http://mmsd1.mms.nrcan.gc.ca/recycle/ICF%20final%20report.pdf> (retrieved 18.03.10).
Instituto de Pesquisa Econômica Aplicada – IPEA & Istituto Nacional de Geografia e Estatística – IBGE, 2004. Millennium Development Goals: Brazilian Monitoring Report. Brasília: IPEA & IBGE. <http://planipolis.iiep.unesco.org/format_liste1_en.php?Chp2=Brazil> (accessed 12.02.12).
Karak, T., Bhagat, R.M., Bhattacharyya, P., 2012. Municipal solid waste generation, composition, and management: the world scenario. Critical Reviews in Environmental Science and Technology 42 (15), 1509–1630. http://dx.doi.org/10.1080/10643389.2011.569871.
Larsen, A.W., Merrild, H., Christensen, T.H., 2009. Recycling of glass: accounting of greenhouse gases and global warming contributions. Waste Management & Research 27 (8), 754–762.
Lino, F.A.M., Ismail, K.A.R., 2011. Energy and environmental potential of solid waste in Brazil. Energy Policy 39 (6), 3496–3502. http://dx.doi.org/10.1016/j.enpol.2011.03.048.
Lombardi, L., Carnevale, E., Corti, A., 2006. Greenhouse effect reduction and energy recovery from waste landfill. Energy 31 (15), 3208–3219.
Lucas, G., 2002. Disposability and dispossession in the twentieth century. Journal of Material Culture 7 (1), 15–22.
Machado, S.L., Carvalho, M.F., Gourc, J.-P., Vilar, O.M., Nascimento, J.C.F., 2009. Methane generation in tropical landfills: simplified methods and field results. Waste Management 29, 153–161.
Mayara, C., 2013, January 01. Ampliação de Aterro Sanitário em Mauá Depende da Electropaulo. ABCD Maior. <http://www.abcdmaior.com.br/noticia_exibir.php?noticia=47052> (accessed 21.02.13).
Medina, M., 2000. Scavenger cooperatives in Asia and Latin America. Resources, Conservation & Recycling 31, 51–69.
Merrild, H., Damgaard, A., Christensen, T.H., 2009. Life cycle assessment of waste paper management: the importance of technology data and system boundaries in assessing recycling and incineration. Resources, Conservation & Recycling 52 (12), 1391–1398.
Ministério da Ciência, Tecnologia e Inovação – MCTI, 2008. Designated National Authority (Interministerial Commission on Global Climate Change) – General Information on the Commission. <http://www.mct.gov.br/index.php/content/view/14666.html#ancora> (retrieved 12.02.12).

Ministério do Trabalho e Emprego/Secretaria Nacional de Economia Solidária – MTE/SENAES, 2011. Edital do chamada Pública SENAES/MTE No. 004/2011: Fomento a Empreendimentos Econômicos Solidáarios e Redes de Cooperação Atuantes com Resíduous Sólidos Constituídas por Catadores e Catadoras de Materiais Reutilizáveis e Recicáveis. Brasília.

Mohareb, A., Warith, M., Diaz, R., 2008. Modelling greenhouse gas emissions for municipal solid waste management strategies in Ottawa, Ontario, Canada. Resources, Conservation & Recycling 52 (11), 1241–1251.

Morris, J., 2005. Comparative LCAs for curbside recycling versus either landfilling or incineration with energy recovery. International Journal of Life Cycle Assessment 10 (4), 273–284.

Najam, A., Rahman, A.A., Huq, S., Sokona, Y., 2003. Integrating sustainable development into the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Climate Policy 3 (Suppl. 1), S9–S17.

Noel, C., 2010. Solid waste workers and livelihood strategies in Greater Port-au-Prince, Haiti. Waste Management 30 (6), 1138–1148.

Olsen, K.H., 2007. The clean development mechanism's contribution to sustainable development: a review of the literature. Climatic Change 84, 59–73.

Pimenteira, C.A.P., Pereira, A.S., Oliveira, L.B., Rosa, L.P., Reis, M.M., Henriques, R.M., 2004. Energy conservation and CO_2 emission reductions due to recycling in Brazil. Waste Management 24, 889–897.

Pipatti, R., Sharma, C., Yamada, M., Alves, J.W.S., Gao, Q., Guendehou, G.H.S., Koch, M., Cabrera, C.L., Mareckova, K., Oonk, H., Scheehle, E., Smith, A., Svardal, P., Vieira, S.M.M., 2006. Waste generation, composition, and management data. In: Eggleston, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, vol. 5: Waste (chapter 2). Institute for Global Environmental Strategies, Hayama, Japan.

Population Reference Bureau, 2011. Human Population: Urbanization. Population Reference Bureau. <http://www.prb.org/Educators/TeachersGuides/HumanPopulation/Urbanization.aspx> (retrieved 10.0212).

Reddy, B.S., Assenza, G.B., 2009. Climate change – a developing country perspective. Current Science 97 (1), 50–62.

Rigamonti, L., Grosso, M., Giugliano, M., 2009. Life cycle assessment for optimising the level of separated collection in integrated MSW management systems. Waste Management 29, 934–944.

Rogger, C., Beaurain, F., Schmidt, T.S., 2011. Composting projects under the Clean Development Mechanism: sustainable contribution to mitigate climate change. Waste Management 31 (1), 138–146.

Satterthwaite, D., 2003. The links between poverty and the environment in urban areas of Africa, Asia, and Latin America. The Annals of the American Academy of Political and Social Science 590, 73–92.

Scheinberg, A., Spies, S., Simpson, M.H., Mol, A.P.J., 2011. Assessing urban recycling in low- and middle-income countries: building on modernised mixtures. Habitat International 35 (2), 188–198.

Schenck, R., Blaauw, P.F., 2011. The work and lives of street waste pickers in Pretoria – a case study of recycling in South Africa's urban informal economy. Urban Forum 22, 411–430. http://dx.doi.org/10.1007/s12132-011-9125-x.

Schor, J.B., 2010. Plenitude: The New Economics of True Wealth. Penguin Press, New York.

Secretaria de Saúde e Higiene de Ribeirão Pires, 2010. Plano Municipal de Saúde de Ribeirão Pires, 2010–2013. Prefeitura Municipal da Estância Turística de Ribeirão Pires. <http://www.ribeiraopires.sp.gov.br/busca.php?busca=plano+de+sa%FAde&submit2=+> (accessed 27.02.12).

Sembiring, E., Nitivattananon, V., 2010. Sustainable solid waste management toward an inclusive society: integration of the informal sector. Resources, Conservation & Recycling 54 (11), 802–809. http://dx.doi.org/10.1016/j.resconrec.2009.12.010.

Sergio, 2010. Cooperpires member. Interview. 25 Feb. 2010.

Shekdar, A.V., 2009. Sustainable solid waste management: an integrated approach for Asian countries. Waste Management 29 (4), 1438–1448. http://dx.doi.org/10.1016/j.wasman.2008.08.025.

SWACH, 2012. What we do helps: Pune wastepickers at climate change conference. SWACH Newsletter 1(2), 2. <http://www.swachcoop.com/newsletter-swachpune.html> (accessed 26.02.13).

Talyan, V., Dahiya, R.P., Sreekrishnan, T.R., 2008. State of municipal solid waste management in Delhi, the capital of India. Waste Management 28 (7), 1276–1287.

Troschinetz, A.M., Mihelcic, J.R., 2009. Sustainable recycling of municipal solid waste in developing countries. Waste Management 29, 915–923.

Tyco Electronics Corporation, 2005. Understanding Leakage Currents. Tyco Electronics Corporation. <http://tycoelectronics.custhelp.com/app/answers/detail/a_id/3776> (accessed 27.02.12).

Uiterkamp, Azadi, Ho, B.J.S., Azadi, H., Ho, P., 2011. Sustainable recycling model: a comparative analysis between India and Tanzania. Resources, Conservation & Recycling 55 (3), 344–355.

United Nations Framework Convention on Climate Change – UNFCCC, 2008. Tool to Calculate Baseline, Project and/or Leakage Emissions From Electricity Consumption – Version 1. UNFCCC. <http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v1.pdf/history_view> (accessed 27.02.12).

United Nations Framework Convention on Climate Change – UNFCCC, 2010. CDM Methodology Booklet. UNFCCC, Bonn. <http://cdm.unfccc.int/methodologies/index.html> (accessed 27.02.12).

United Nations Framework Convention on Climate Change – UNFCCC, 2011a. AMS-III.A.J.: Recovery and Recycling of Materials from Solid Wastes – Version 3.0. UNFCCC. <http://cdm.unfccc.int/methodologies/DB/I09S4G8NFK11QYSD4O9FTGM18K9NYK> (accessed 27.02.12).

United Nations Framework Convention on Climate Change – UNFCCC, 2011b. Tool to Calculate the Emission Factor for an Electricity System – Version 2.2.1. UNFCCC. <http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.2.1.pdf/history_view> (accessed 27.02.12).

United Nations Framework Convention on Climate Change – UNFCCC, 2011c. Tool to Determine Methane Emissions Avoided from Disposal of Waste at a Solid Waste Disposal Site – Version 05.1.0. UNFCCC. <http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v6.0.0.pdf/history_view> (accessed 27.02.12).

United Nations Framework Convention on Climate Change – UNFCCC, 2012. About CDM. UNFCCC. <http://cdm.unfccc.int/about/index.html> (accessed 10.02.12).

United Nations, 2011. The Millennium Development Goals Report 2011. United Nations, New York.

United States Environmental Protection Agency – US EPA, 2006. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, third ed. US EPA. <http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html> (accessed 26.02.12).

Wilson, D., Velis, C., Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. Habitat International 30 (4), 797–808.

Wilson, D.C., Araba, A.O., Chinwah, K., Cheeseman, C.R., 2009. Building recycling rates through the informal sector. Waste Management 29, 629–635.

World Bank, 2009. Project Information document: Integrated Solid Waste Management and Carbon Finance Project, Report No. AB3924. World Bank, Washington, DC. <http://www.worldbank.org/> (accessed 22.02.12).