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Jutta Gutberlet, Torleif Bramryd, and Michael Johansson

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Article

Expansion of the Waste-Based Commodity Frontier: Insights from Sweden and Brazil

Jutta Gutberlet ^{1,*} , Torleif Bramryd ² and Michael Johansson ²¹ Department of Geography, University of Victoria, Victoria, BC V8P 5C2, Canada² Environmental Strategy, ISM, Campus Helsingborg, Lund University, PO Box 882, SE-251 08 Helsingborg, Sweden; torleif.bramryd@ism.lu.se (T.B.); michael.johansson@ism.lu.se (M.J.)

* Correspondence: gutber@uvic.ca

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Abstract: Waste is a valuable commodity and remains a livelihood source for waste pickers in the global South. Waste to Energy (WtoE) is often described as alternative to landfilling, as it provides cheap fuel while making waste disappear. In some European cities, this method has evolved into an impediment, slowing down the adoption of more sustainable technologies and waste prevention. These plants typically strain municipal budgets and provide fewer jobs than recycling and composting, thereby inhibiting the development of small-scale local recycling businesses. We applied the idea of ‘waste regime’ with an interdisciplinary and situated lens to provide insights to the following questions: *How do different political developments in Brazil and Sweden, frame and reframe waste incineration and energy recovery, in the context of sustainability and waste management on local, regional and national levels? What forms of resistance against WtoE exist and what are the arguments of these protagonists?* We evaluated the impact of WtoE and compare it with other waste management options with regard to CO₂ balances and general environmental and social impacts. We conclude by suggesting more socially and environmentally appropriate ways of waste management, particularly for the context of global South cities.

Keywords: waste management; waste to energy; biogas; material recycling; circular economy; waste pickers; waste regime; sustainability; Brazil; Sweden

1. Introduction

Municipal solid waste (MSW) has evolved into a critical challenge for cities and their inhabitants. How we approach waste and what we do with it is of great importance to our society and the planet in general. With industrialization and increased urbanization since the advent of mass consumption and disposability, waste has become extremely complex in material composition. It has become pervasive and ubiquitous in geographic distribution. Waste that is collected needs an adequate final destination and waste that is not collected becomes an environmental health threat. ‘Waste regime’, a concept adapted by Gille Zsuzsa [1], describes the multifaceted aspects of governance and waste management which helps understand the waste—society relationship and addresses questions such as: What technologies are being used in waste management? Why are these technologies prioritized? Who is involved in the production, circulation and transformation of waste? The concept helps understand why projecting waste out of sight is not enough. Waste regimes are dynamic, historically contextualized and geographically situated. Waste regimes have particular economic, political, material and macro level facets, that shape production and transformation of waste. This also allows us to identify winners and losers within the waste business.

Waste often is or becomes a hazard, depending on the waste management technology in use, creating environmental problems affecting air, water and soil quality. Waste disposal sites and

incineration plants create greenhouse gas emissions. Even the siting of these facilities becomes a problem, since nobody really wants them close by. There are alternative discourses and philosophical perspectives on waste. The academic literature deals with it primarily as a problem requiring management for ecological, economic, and public health reasons [2]. A social science lens on waste shows that it is also a disputed resource and lucrative commodity, involving different stakeholders, with particular interests and agendas, which are sometimes in conflict [3–5]. Significant contributions have also been made on the subject by several authors, providing a specific global South lens [6–13].

This article describes the waste management strategies adopted for household waste in Sweden and Brazil and discusses some of the implications of the current waste regime. We chose these two countries, based on the particular stage of the waste regime that characterizes their waste management system, despite the large differences in economic, social, political and cultural terms between these two countries. In Sweden where waste incineration has played a significant role in the past, new perspectives and alternatives are emerging now. In contrast, in Brazil incineration technology is currently expanding.

Waste to Energy (WtoE) is widespread in the global North and is now also promoted as solution to waste challenges in cities in the global South, altering the local waste regimes. There is evidence that WtoE is problematic in the global South context, creating new social and environmental impacts. Coming from a critical theory perspective we will reveal how WtoE bares risks of further accumulating wealth among waste management businesses, while dispossessing the most excluded population, waste pickers, who have historically reclaimed recyclables from waste, as is the case in Brazil. While the majority of the waste pickers still mostly operate informally, a growing number has organized, operating with various levels of integration in formal waste management, through different collaborative arrangements with government, industry, service providers and civil society organizations as well as with diverse degrees of public policy support [8,14,15]. Whether organized or not, waste pickers have agency and particularly when challenged by proposed WtoE projects, they mobilize and resist. The global North critique to WtoE is emerging, in view of climate change mitigation objectives, questioning this technology for not meeting the required standards to reducing greenhouse gas emissions. Nevertheless, in Sweden, a techno-scientific discourse still predominates current practices, with little community involvement. We want to explore particularly these differences and similarities in current waste management between these two countries.

Our article bridges a knowledge gap by analyzing possible impacts from transferring waste management technology from the global North to the global South. We begin by discussing different understandings of waste and introduce the concept of waste regime. We describe the development of the waste regimes to the present situation in Brazil and in Sweden. We highlight the difference between waste management in the North and the South contrasting automatization and centralized solutions, with work intense processes of resource recovery and transformation. Finally, we explore grassroots social technologies from the global South, as alternative to WtoE, and will point towards more appropriate and better technical solutions.

2. Methodological and Theoretical Framework

Our paper is based on an exploratory research approach, grounded in the analysis of current waste management trends in Sweden and Brazil, helping us gain insight into the dominant waste regime and possible changes. Sweden will be used as example for a country in the global North, which has invested heavily in waste management technology and is one of the leaders in terms of waste incineration, yet recent findings are questioning the sustainability of this form of final destination for waste. Brazil will stand as an example for several other countries in the global South, where governments are recently considering waste incineration as part of their waste management practices. Yet, like in many countries in the global South, waste pickers are widely engaged in recovering recyclables from the waste stream, inserting them back into the circular economy. Our selection of the two cases is supported by the fact that the authors have a long standing experience in waste management, drawing on research

experiences from previous projects as well as from current debates with scholars, practitioners, social movements and community. One author brings long-term international expertise with participatory action research with waste pickers in the global South while the other two authors are international experts in the field of waste management.

Key informant in-depth interviews, participatory observation and the collection of secondary data informs the case studies. Fieldwork was conducted in the metropolitan region of São Paulo between May and July 2017, while the Swedish case is primarily informed by secondary data and information collected during conferences and seminars. The two case studies were systematically analyzed through a combination of academic literature review and analysis of waste management documents in both countries and providing a novel understanding of possible impacts from transferring WtoE to Brazilian and other global South cities as well as a shift towards more sustainable treatment measures in countries like Sweden.

2.1. Waste Conceptualizations

What is waste? Waste has many understandings depending on the social, economic and political perspectives and the ontological lens which is applied. Most people perceive waste as a nuisance, to be distanced from, as quick as possible [4]. In low income or minority neighborhoods dumping of waste (including hazardous and toxic waste) is most visible and creates disparate burdens within society [16]. Health hazards related to waste become obvious particularly when waste is not collected and when it accumulates in drainages, rivers or beaches, causing water-logging, inundations, or littering of the urban landscape [17,18].

To most governments waste is a manageable object, to be governed with managerial tools, through privatization of the sector and with engineering alternatives [15]. From that perspective business provides the solutions and fills the management gaps, most often with expensive, large scale technology (e.g., automatized recycling stations, waste incinerators, multipurpose 'compactor' garbage collection trucks). Recycling, as part of waste management, is widely seen as a betterment of the waste problem but the social or technological aspects involved are hardly ever questioned.

Waste is positioned as a good to be traded and or regulated through market mechanisms and is used to create wealth and economic growth. For the waste management sector, in particular, waste is a profitable commodity with market value. It is no news that waste management and trade, particularly in the global North, have already created a multi-billion-dollar industry [19]. One of the major waste-based commodity frontiers today, we will argue, lies in the big cities and metropolitan regions in the global South. We will demonstrate that businesses (national or multinational corporations) are taking great interest in the waste market, expanding WtoE technologies. In many cities in the global South, neoliberal governments promote the agenda of privatizing public services, including waste management, which boosts these companies' interests in exploring this commodity frontier in the global South, translating into attractive markets. Waste pickers have agency, which sometimes allows them to actively shape the waste regime, as reveals the Brazilian case, where waste pickers reaffirmed themselves as protagonists in resource recovery and reverse logistics. In many cities in Latin America, waste pickers have created alternative models for collecting, sorting and selling the recyclables they recover from household waste (and sometimes business or industry waste), which has led them to invent and develop complex systems and technologies specific to their daily operations [12].

Other than conceptualizing waste as nuisance, hazard, manageable object or commodity, waste can also be understood as resource, to be recovered as livelihood strategy; particularly by the dispossessed in the global South. This is of great relevance to recyclers, who see value in what most people discard as worthless or rubbish and they recover and re-enter diverse materials into cycles of reuse and economic production [7,20].

2.2. The Waste Regime Perspective

Critical systems theory understands cities as complex socio-environmental systems, just like metabolisms with different material and energy flows, highlighting the circularity in production, consumption and discard, fluxes, networks, and processes of metabolically transformed nature from a new 'socio-natural hybrid' [21]. The systems perspective identifies those flows, linkages, actors, technologies, social relations and power dynamics that happen in city management and decision making, also with respect to waste management [22]. The approach helps to identify and correct sociotechnical impacts of infrastructure, networks, and resources flows. Landfills, incinerators, recycling centers, trucks and other equipment is part of the urban infrastructure and is a manifestation of governance and power relations [23,24].

Derived from Young's idea of 'resource regime', [1] proposes the term 'waste regime', to apprehend the multi scalar societal aspects of waste, from waste production, consumption, circulation, transformation to waste prevention. Waste regime is a macro level concept which beyond, modes of governance and the specific issues related to access, networks and waste flows further analyses the economic, social, and cultural logic of the generation of waste. It challenges the normalized assumption that waste should be put out of sight.

WtoE is a form of quickly disassociating us from waste and making it visually disappear, without in fact, solving the problem, but creating air contamination and residual ashes requiring remediation. The widespread current waste regime is focused on privatization of public waste management services, low levels of public participation, and waste management technologies that prioritize large scale solutions. While in the global South, large numbers of waste pickers are involved in municipal waste recycling, yet, local politics are often disconnected from the social realities, resulting in accumulation by dispossession, affecting the livelihoods of waste pickers [25].

When city administrations handle waste with expensive technology (e.g., WtoE) they risk to become locked-in over time, thus slowing down the emergence of more sustainable urban infrastructures and behaviors [26]. Based on institutional, technical, cultural, and material rationale the lock-in guarantees the accumulation of waste resources and capital, it favors the continuation of mass consumption, planned obsolescence and discard, while dispossessing the commons who have been reclaiming those materials since long. Waste has become a disputed resource between governments, the private sector and the waste pickers [27].

The next section will introduce the development of the current waste regime in Sweden and Brazil, drawing specific attention to the role of waste incineration (WtoE) and public or cooperative involvement in waste management in these countries. Urban agglomerations in the global South have become the new frontiers in waste management, as these cities are struggling with exponential increase in waste.

3. Waste Management in Sweden

In Sweden, low-waste technology and material recycling are key factors for planning future waste minimization systems since the 1930s. A new waste regime based on single use and throwaway evolved, with the development of new self-service stores and supermarkets, and the prominence of plastics as packaging material and as one-way carry home bags. This meant a rapid increase in waste volumes, which resulted in landfills quickly filling up; a circumstance which trickled the discussions about incineration as a solution. By the 1950s, Sweden already had built three major incinerators (Stockholm, Uppsala, Linköping) for waste destruction.

With the global energy crisis in the mid-1970s and with the rapidly increasing waste volumes new incinerators were built. A deep concern about air pollution was raised which resulted in intense debates involving environmental organizations, researchers and authorities. To avoid building incinerators, a new Governmental proposition, in 1992, emphasized the need to reduce waste volumes, and demanded that all material should be seen from a recycling perspective. In order to enforce this, producer responsibility was introduced and fees were established to pay for the cost of recycling. This

system became mandatory in all communities in Sweden, but the effectiveness varied from place to place. In 2000, it was also decided that food waste should be collected separately for the use as raw material for biogas production.

Before the 1970s most of the waste collection in Sweden, with few exceptions, was carried out by municipality cleansing departments. Since the 1980s, all cities, also in remote rural areas, must be connected to municipal waste collection systems. Waste collection can be done by a city department, a city owned company, or contracted out, after procurement, to a private transportation company, which takes the MSW to the treatment facility. In most cases the treatment facility is owned by the city, or by several cities collaborating as a municipal company, but it can also, to an increasing extent be owned by private companies. Today, a majority of the cities in Sweden use private entrepreneurs for the collection of MSW. The expansion of waste incinerators was justified with the argument to supply energy, mainly for district heating, and thus decrease the demand for oil. An increasing amount of plastics with fossil origin had increased the calorific value of the waste, even if much of the energy was needed to evaporate the water from moist organic waste during the incineration process. A stronger argument, however, seems to be that it had become increasingly more difficult for cities to find new landfill sites, due to the NIMBY effects. Incineration was also perceived as a way to reduce the waste volume before landfilling, thus prolonging the life span of landfills. At the same time, due to the stack-gas emissions of heavy metals, acidifying substances and organic polyaromatic compounds, such as dioxins and dibenzofurans, public opposition against incineration had increased.

In Sweden, waste incinerators are mainly managed by municipalities or companies owned by the municipality. During the 1990s, the Swedish State Department of Energy and other financing authorities invested large amounts to develop new waste management techniques based on material recovery and biological treatment. Due to the increased demand for energy, biogas formation from fermentation of MSW was devoted major interest [28].

The first landfill gas extraction unit was built in Malmö in 1984, followed by Helsingborg the year after. The State Department of Energy invested heavily in research and development to improve the landfill gas technique, resulting in the creation of the bioreactor cell technique, with optimal and controlled fermentation to be installed at landfills. In the bio-reactor cells a total biogas extraction rate of about 120 m³ of biogas per metric ton of waste over the period of 10 years was found and about 12 m³ of biogas per metric ton of waste per year. In the experiments at the SYSAV plant in Malmö about 90–95% of the produced biogas could be extracted and recovered from the bioreactor cells. The effective collection of landfill gas combats climate change as the remaining organic residues in the landfill act as carbon sink reducing atmospheric CO₂ concentrations. On the other hand, if less than about 60% of the produced biogas is collected the negative effects of methane as a greenhouse gas prevail. Most controlled landfills nowadays collect at least over 75% of the produced landfill gas. Through mechanical pre-treatment and improved mixing of the waste, the biogas production can be improved and concentrated in time, and the volume reduction of the waste is considerable, due to the optimized degradation processes. Due to the good performance of the bioreactor cell technique many waste companies with incinerators consider this technique as a future replacement of incinerators [28].

However, during the late 1990s, due to strong lobbying among incinerator owners in Germany, who wanted to secure MSW as a cheap fuel in their power plants, the EU imposed severe restrictions on landfilling of combustible and other organic waste. Thus, many cities in Sweden started to build incinerators, expecting to get waste also from surrounding regions. This resulted in an extensive overcapacity in incineration, which lead to a massive import of MSW from other European countries. In 2017, 1.49 million tonnes of waste were imported from other European countries for treatment at Swedish plants. There are 34 incinerators for household waste operating in Sweden, among Europe the country with the highest rates of incinerators per inhabitant [29]. In Sweden the techno-scientific discourse and practices determine the current waste regime, while public participation has merely drawn the attention to the health implications of waste incineration. Today climate change

preoccupations seem to become the forces that challenge WtoE and mobilize for searching more feasible waste management strategies.

Much research in Europe, including, e.g., LCA studies, is devoted to increase the effectiveness of waste incinerators and improve the combustion processes to reduce emissions [30–33]. In Sweden however, the main focus today is on the emissions of fossil CO₂ from incinerators and how these can be reduced through the reduction of plastics and other synthetic material in the waste. Moreover, the emissions of N₂O a strong greenhouse gas in the stack gasses from incinerators, resulting from some NO_x reducing techniques, are of recent focus. In addition, through the development of a stricter source separation procedure already in the households, in combination with better information and education, the amount of MSW for incineration is expected to decrease significantly.

In order to decrease the volume of waste to be incinerated, and especially the amounts of imported waste, the current Swedish Government has introduced a tax of 70 SEK (about 7 €) per metric ton on all waste that is incinerated. This tax will in the coming years increase to 200 SEK (20 €) per metric ton. The goal is that no new incinerators have to be built in the future due to the enforcement of a better circularity.

The trend among all governmental authorities, politicians, cities and planners is to invest heavily in the circular economy. The aim is to achieve a “zero residual waste” strategy strongly reducing future use of incineration or final landfilling. More or less everything that is found in the residual waste today is supposed to be brought to a second or third life. This includes new recycling systems for textiles, synthetic fibres, different types of plastics and other packaging materials.

Second-hand shops are being increasingly popular to get a prolonged life to products, but also workshops where people can repair clothes, shoes, furniture, etc. Sometimes this is a measure to generate livelihoods for people included in social security work. France recently has created a legislation (Project to curb waste and to stimulate circular economy) [34]. This extensive text includes, among other things, an obligation to inform the consumer about the repairability (and about the shelf life) of products, a ban on the destruction of unsold products and a strategy regarding plastics (single-use plastics and microplastics, such as added to cosmetics and personal care products). This is the first piece of legislation coming from an EU member state to advocate for reparability assessment [34]. It is likely that the results of this initiative will be used to design the EU’s new circular economy action plan as well.

In a project financed by the Swedish Department of Energy wood waste, old furniture, etc. is used as raw material for production of fibre board in several cycles. After the final use of the wood fibres in building material, they can be used as a filter for eutrophicated water, and finally composted to produce soil improvement. Tannins as a non-allergic alternative for formalin, is also extracted from wood waste to be used as glue for fibre boards [35,36]. New more effective sorting facilities for mixed plastics are built in *Värnamo* and *Lanna*, which will increase the material recovery of plastics.

MSW is regarded as partly a “fossil fuel” when incinerated, and a new facility is built in Stockholm to separate plastics from the waste before burning in the incinerator. Around 30% of the carbon dioxide in the stack gasses from an MSW incinerator is of fossil origin, and Sweden thus has an intension to reduce waste with fossil origin. To work in this direction, a new tax of 3 SEK is laid on all one-way plastic bags in shops, in order to reduce the annual consumption to only 40 bags per person and year.

Landfill mining is a technique developed in many European countries [37–40]. In Sweden, however, this technique is not economically realistic today. One reason for this is, that the non-recoverable residues from landfill mining have to be landfilled or incinerated, and then these amounts are subjected to disposal fees and taxes. Thus, landfill mining is only used in situations where the area has to be sanitized or when the area has a high market price for new housing developments. Otherwise restored landfill areas are used for parks, golf courses or as recreational areas. However, in the far future, when, e.g., metal resources or plastic polymers will become scarcer, landfill mining with new techniques can be an important way of mining material resources. Thus, landfills can be regarded as future resource banks, with a high value in the far future.

4. Waste Management in Brazil

In Brazil, the annual rate of increase in household waste generation (1.7%) is lately growing more than twice as much as the population growth rate (0.8%), which places significant stress on city administrations to deal with increasing amounts of municipal waste [41]. Today, over 90% of the total 206 million people in Brazil has access to waste collection services. The final destinations are sanitary landfills (59%), controlled landfills (24%) and waste dumps (17%). Thus, 41% from formally collected waste still has an inadequate final destination. 60% of Brazil's municipalities face severe challenges in waste management, due to illegal dumping, inadequate or inefficient infrastructure and lack of resources [30]. Brazil's waste regime is still primarily based on dumping and landfilling and is facing an exponential increase in waste generation, based on throw-away and planned obsolescence, since the 1980s. Then a perception of waste as a nuisance and environmental health hazard was prevailing. Until 2010, waste governance was a top down business with no official space for waste diversion or waste minimization.

With the approval of the National Solid Waste legislation (Federal law no.12,305/10, regulated by Decree no. 7404, on 23.12.2010) in 2010, recycling has officially become a priority within the waste hierarchy. Waste pickers in Brazil are organized in a national movement (*Movimento Nacional dos Catadores de Materiais Recicláveis—MNCR*), which has been involved in the design of this federal policy. As a result, organized waste pickers are to be prioritized in municipal selective waste collection and reverse logistics projects. The law makes specific reference to waste pickers in 11 articles, as a result of their input in designing this national waste legislation [10]. These achievements have been the drivers for most of the waste picker organizations in Latin America, spearheading their demands to be recognized as protagonists in waste management concerned with waste prevention strategies [9]. Brazil also has significant experiences in developing a Social and Solidarity Economy and has recently approved a National Solidarity Economy Policy (Project Law PLC 137/2017). Specific programs under Brazil's Solidarity Economy have strengthened the organization of the waste pickers and the integration of their organizations into official waste management.

Yet, despite the federal legislation, waste management is still understood as sanitation issue, a nuisance and hazard, by local governments, without recognizing the important livelihood opportunities in recycling. The main protagonists, these waste pickers, are often left out of formal waste management [42]. Waste pickers reclaim materials from the waste stream, separate and sell them to scrap dealers or—if organized—directly to the recycling industry. They are autonomous skilled workers, specialized in classifying a large number of complex materials within the waste stream. Depending on their level of organization (from independent workers to organized members in cooperatives, associations and networks) and availability of infrastructure (e.g., recycling depot with electricity and water) and equipment (e.g., carts, trucks, presses, sorting tables or conveyer belts, forklifts, balances, computers, software) they also collect other materials including cooking oil, fluorescent lamps, wood, electric and electronic waste and may work with large waste generators (e.g., industries, offices, businesses, government institutions). In some cases, recycling cooperatives add value to these collected materials (e.g., pelleting plastic, transforming PET bottles into washing line, making boards out of aluminium, plastic and cardboard mixed packaging). A recent survey counted 387,910 *catadores* in Brazil [43], of which 30,390 were organized in 1175 cooperatives and associations, in 684 municipalities in Brazil [44]. According to the non-governmental source CEMPRE (*Compromisso Empresarial para Reciclagem*) there were 1,055 municipalities in Brazil, operating formal selective waste collection programs, which is 18% of all municipalities in Brazil [45].

The current waste regime in Brazil is characterized by a sociotechnical system that prioritizes outsourcing of waste management. Since 2010, different forms of public private partnership arrangements have become more popular in waste management, re-shaping the waste regime, into the following different scenarios:

- (a) outsourcing waste collection, using trucks in door to door collection and transporting the waste to the local landfill;
- (b) outsourcing selective waste collection, using trucks (sometimes compacting trucks) providing these materials to recycling centers and recycling cooperatives run by waste pickers;
- (c) involving recycling cooperatives in the collection, separation and redirection of materials into the recycling economy with or without formal contract (and remuneration of the diversion services) between the city and waste pickers;
- (d) establishing public private partnerships to acquire new technologies for material recycling (e.g., large-scale automatized material separation), or for material incineration and energy generation (WtoE);
- (e) emergence of new enterprises to collect and concentrate recyclable material from large generators and to sell to recycling industries, without the involvement of waste picker organizations.

The National Solid Waste legislation requires municipalities to develop a waste management plan, close waste dumps and move away from unsanitary landfills. Municipalities are considering different options to achieve these objectives—scenarios (a) to (e). Yet, by 2014, only 33.5% of the Brazilian municipalities had elaborated an integrated solid waste management plan, servicing 37.3% of the total population [46]. Many cities are behind the targeted goals. The legislation prioritizes contracts with cooperatives for recycling (options b and c); yet very few municipalities have committed to working primarily with recycling cooperatives. With waste generation increasing and the lack of new adequate landfill sites, the option of WtoE becomes more attractive. Currently, São Bernardo do Campo (SBC) and Barueri have plans for moving towards WtoE in the metropolitan region of São Paulo. Given the high investment, complicated bureaucratic approval process and resistance from the civil society, this project in SBC, which was initiated in 2008, has been put on hold. Despite public opposition, a Public Private Partnership (PPP) has been developed to initiate the construction of a WtoE plant (*Mass Burn*) in Barueri, in 2017. The plant is projected for the capacity of 825 tons/day, generating 17.5 MW/h. To date, there is only one commercial WtoE plant for household waste in operation in Brazil (Unai, Minas Gerais). Several others are proposed, as shown in the following figure (Figure 1). The data represented here are the result of secondary sources and interviews with key informants (waste specialists and NGOs working on waste issues).

Waste pickers perceive the accumulation of wealth, in a waste regime that favors high tech over grassroots social technology, and that furthers dispossession of the poor by reducing the access to recyclable materials. Ana, a waste picker in São Paulo emphasizes: *recycling is life, so many people today survive from recycling. I say recycling is life, because I have created two children by collecting recyclables. . . . there is also the sense of helping the environment. But they [WtoE] got in between because they know it [waste] has value, but they do not want to give value to waste pickers. The incinerator will only ruin the environment and people's lives"* (Interview with Coopercata, 7th of July 2017). Resistance to WtoE comes not only from waste pickers, but also includes NGOs and social movements who contest WtoE and support inclusive waste management. They see organized waste pickers as important actors in waste management and as grassroots innovators in city making [47]. The next section examines new current developments in Sweden, shifting away from WtoE, while in Brazil, there is an increased interest in household waste incineration.



Figure 1. Proposed and existing waste incinerators in Brazil. Source: Empirical data collected with key informants in Brazil in 2017, by the authors.

5. Discussion: The Prevailing Waste Regimes in the North and in the South and the Expansion of the Waste-Based Commodity Frontier

The two case studies highlight similarities and differences in how waste is dealt with. In Sweden, throw away and planned obsolescence during the early 1970s as well as the demand for heat in district heating systems, has promoted technology developments in incineration, WtoE, bio-reactor cells, and improved landfill gas recovery techniques. Overall this has intensified the construction of WtoE plants, despite public opposition. With growing recent concerns over climate change a rethinking has begun, questioning the superiority of WtoE over other forms of waste management in Sweden. In Brazil, rapid urbanization, population growth, mass consumption and the expansion of plastic packaging since the 1980s resulted in increasing amounts of waste to become deposited at dumps and landfills, or remained uncollected. Only with the introduction of the recent federal solid waste legislation, there was a shift in the waste regime towards increased recycling and reverse logistics.

For a long time, waste has been treated as a commodified resource of value to the industry. Likewise, waste has been conceptualized as merchandise to waste pickers, providing them with a livelihood. Waste pickers are punished for collecting recyclable materials and waste is treated as private property by the local government or companies in charge of waste collection. Constant struggles over gaining access to waste materials has reframed waste into a resource for the commons, by and for the waste picker populations in the global South [3,36]. This situation has changed, with the advent of the waste-based commodity frontier and the investment opportunities that have further opened in waste management.

The Brazilian case shows some of the institutional mechanisms currently at play that produce waste-based commodity frontiers. While the national waste pickers' movement participated in the design of the legislation and was able to insert significant reference to organized waste pickers, an industrial lobby was also involved and in favor of waste incineration. Earlier drafts of the legislation

did not include incineration as part of the waste management hierarchy. According to MNCR, industrial lobbies have managed to alter the law in a last-minute act, permitting waste incineration as an option [48]. While this legislation is still innovative in establishing dialogue between city administrators and waste pickers and delegating roles in waste management to different sectors of society including the waste pickers, it has opened the doors to environmentally and socially unfriendly technology.

In Sweden, greater focus on air emission controls resulted in the development of new stack-gas emission systems, rather than only electro filters, like bag filters and wet scrubbers. However, these techniques only capture particles with a size bigger than 0.3–0.5 μm in size, while the heavy metal bearing particles from burning of paper and plastics often are very small, around 0.1 μm in size. The problem with these small particles is that they can be inhaled and be transported down into the human lungs without being stopped by the cilium in the respiratory system, and are thus more toxic to the human body. When problems with dioxin and dibenzofuran emissions from waste incineration were highlighted, a moratorium was put on building new waste incinerators in Sweden, in 1985. The moratorium lasted for one year, but was lifted under the condition that the purification technique and especially the combustion conditions had improved. Limits were set for dioxins, heavy metals, and acidifying gases in the stack gas, based on regular measurements.

Changes in waste management regulations have become apparent in several cities in the global South, where contracts are increasingly awarded to the private corporate sector for the collection and process of waste. Public private partnerships are established to acquire expensive technology. These developments have begun further dispossessing waste pickers of their rights to access the recyclable fraction of waste.

While in the global South, social economic aspects play a huge role in decision making over waste management and technologies, in the global North climate change aspects are in the forefront, questioning whether landfills and incinerators are good or bad from a climate change perspective. This is a major concern in Sweden, where cities and regions more or less compete with each other to be as environmentally friendly as possible.

About 30% of the carbon dioxide in the stack gases from an incinerator is of fossil origin [29], and thus cities or regions with waste incinerators can never be regarded as “fossil fuel free” regions. Incinerators using urea for removal of nitrogen oxides from the stack gases normally also emit portions of dinitrogen oxide (N_2O), which is much more aggressive to the ozone cover than methane. We can infer that incinerating inorganic waste for WtoE is an environmentally and socially problematic approach to waste management. It increases climate change effects everywhere and furthers social exclusion in the global South.

Are landfills currently still the better option as final destination of unrecyclable waste? During landfilling, the organic matter, resistant to degradation, remaining in a bioreactor cell or a landfill acts as a carbon sink for long-term storage, when most of the easily degraded material has been turned into methane or carbon dioxide. For a landfill accepting about 100,000 metric tons per year this can make up for the annual carbon dioxide emissions from approximately 15,000 cars [49]. If methane gas escapes at a high rate to the atmosphere, this can cause a major damage to the atmospheric ozone layer and can contribute to increased global warming. Nevertheless, if more than about 60% of the produced biogas from a landfill is collected, the landfill has a less negative impact and counteracts global warming. Most landfills in, e.g., Sweden collect around 70–80% of the produced landfill gas, and the bioreactor cells recover up to 95% of the biogas. Subsequently, it is important to improve the collection of landfill gas on an international basis [50].

Today, biogas (recovered from landfills or bioreactor cells) has the lowest carbon footprint of available renewable energy and can be used as fuel for transportation, while at the same time it is helping to solve the waste problem. The extraction of biogas from municipal waste causes a number of positive effects that counteract and balance negative climate effects. A prerequisite for biogas systems to have good greenhouse gas performance is to minimize methane emissions [51]. The most important

effect is that the biogas most often replaces fossil fuels, thereby reducing the emissions of fossil-derived carbon dioxide. Greenhouse gas emissions associated with land use change affect the radiation balance and lead to a warmer climate [52]. The disadvantage of biogas as a vehicle fuel is that the production is essentially local, and that there is usually only one local biogas supplier in each municipality [53]. The backbone of such a biogas system should of course be based on local production of renewable fuels [54–56]. The main reason for a conversion to renewable fuels is today the reduction of greenhouse gases [57].

If non-contaminated waste is used for fermentation, the residues can be composted and used as soil improvement. For mixed solid waste, the nutrients can be extracted in the form of leachates from a bioreactor landfill. During landfilling under strict anaerobic conditions most heavy metals (metals with a high atomic weight) are bound up as metal sulphides or as resistant oxides, while the nutrients (mainly metals with a low atomic weight) are washed out and collected as leachate. In Sweden, the landfill leachate is often treated in a so called “soil vegetation system”, where the leachate is used to irrigate, e.g., an energy forest to produce biomass which in turn can be used as an energy resource. The ashes contain low concentrations of pollutants and can be returned as fertilizer to forests. Thus, in this way a bioreactor landfill is also a way of extracting nutrients from the residual waste, to be brought back into an eco-cycling [49].

Regardless of technology development for fossil fuel-efficient fuels, limited infrastructure (both load and gas tank infrastructure) and costly initial investment are major challenges, at least initially. Therefore, a local political clarity and awareness of governance are required, as well as the priority for environmentally and climate-efficient decision making over waste management technologies.

In the context of the global South, waste management offers opportunities for socio-productive inclusion. The activity of collecting and sorting waste, working independently or collectively, creates many jobs [58]. A study by the Brazilian Institute of Applied Economic Research [44] recognizes the cost saving economic contributions as well as the environmental benefits accumulated through material recycling. IPEA estimates a cost saving of R\$ 8 billion every year, in Brazil, if all recyclable materials, currently deposited at landfills would be recycled. With WtoE these savings would not occur. The recycling rate per waste picker is estimated between 606 to 1608 kg/person/month depending on skills and the type of equipment available ([44] p. 8). Significant numbers of jobs could thus be secured through resource recovery and recycling. Providing support to those who already do this job seems like a sensible way to address waste management, particularly in lower income context.

Many questions still remain open in relation to the expansion of the waste-based commodity frontier in global South countries and the social, economic, environmental and cultural impacts of it are not all known. This paper does not go in-depth into all these challenges, but rather provides a general overview of current trends in waste management. Our research discusses the recent developments in the metropolitan region of São Paulo as one of the case studies. Case studies bring a certain limitation that comes with wanting to generalize or upscale case study knowledge. We have limited this bias, by providing a broad literature review on the topic and relating our cases to the literature.

6. Conclusions

Waste management has gone through several stages during the last century. Increased volumes of waste and exponential diversification of waste materials, in combination with a growing environmental concern are calling for waste management techniques that use waste as a resource instead of a burden. With the two cases we have deconstructed the myth of the current dominant waste regime, which suggests to expand the waste-based commodity frontier with WtoE. The use of waste as a raw material for energy production should only be applied for such waste that cannot be re-used or recycled, like residues from food processing that could be used for biogas production [59].

Landfills are important long-term accumulators of organic carbon, and thus can balance increased carbon dioxide emissions to the atmosphere by human activities. Provided that a major part of the landfill gas can be collected, landfills also avoid further CO₂ equivalent emissions. Landfill mining is

already a recognized form of resource recovery. WtoE does not provide these benefits. Once a resource has been burnt it is impossible to recover it for other uses or to transform into new materials.

Particularly important for the context of global South cities is the fact that WtoE takes away jobs. While in Sweden critical voices are emphasizing a shift away from WtoE towards more environmentally and climate-efficient solutions, waste management corporations are eyeballing waste-based commodity frontiers for investment opportunities. This development is contested by the waste pickers in Brazil and in other global South countries. They perceive that jobs are jeopardized, and they understand that reuse and recycling is better than burning these resources. In many cities in Brazil, protests happen regularly against waste incineration, led by organized waste pickers, their social movement (MNCR) and other civil society organizations and individuals. Grassroots recycling benefits specially women, minorities, as well as vulnerable and marginalized populations. Resource recovery creates those necessary 'low barrier' jobs as no other sector does. Furthermore, reuse and recycling links to the circular economy and have the potential to create environmental benefits, including the reduction of virgin natural resource extraction. Yet, foremost resource recovery for recycling and reuse and the recovery of gas generated at landfills or with bioreactor cells is a crucial measure for climate change mitigation. These are cutting-edge topics that need to be investigated in waste management and discard studies. An interdisciplinary lens is needed to uncover and respect situated understandings of waste.

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