UNIVERSIDADE ESTADUAL DE CAMPINAS
Faculdade de Engenharia Mecânica

OCTAVIO PIMENTA REIS NETO

Economic Viability, Socioeconomic and Environmental Impacts from a Large-Scale Model of Urban Solid Waste Treatment in the Metropolitan Region of São Paulo

A Viabilidade Econômica e os Impactos Socioeconômicos e Ambientais de um Modelo de Tratamento de Resíduos Sólidos Urbanos de Larga Escala na Região Metropolitana de São Paulo

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Orientador: Prof. Dr. Marcelo Pereira da Cunha

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Autor: Octavio Pimenta Reis Neto
Orientador: Prof. Dr. Marcelo Pereira da Cunha

A Banca Examinadora composta pelos membros abaixo aprovou esta Tese:

Prof. Dr. Marcelo Pereira da Cunha , Presidente
Universidade Estadual de Campinas - UNICAMP

Prof. Dr. Joaquim E. A. Seabra
Universidade Estadual de Campinas - UNICAMP

Prof. Dr. Waldir A. Bizzo
Universidade Estadual de Campinas - UNICAMP

Dr. Luciano B. de Oliveira
Empresa de Pesquisa Energética - EPE

Dr. Marcos D. B. Watanabe
Laboratório Nacional de Ciência e Tecnologia do Bioetanol - CTBE

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Dedicatória

Aos Cidadãos, que acham que o problema do lixo urbano se resolve simplesmente com a coleta na porta de sua casa.

Aos Políticos, que ignoram a importância da destinação e tratamento dos resíduos sólidos urbanos, por não entenderem ser esse um tema eleitoral.

Aos Pesquisadores que, por ideologia ou interesse próprio, dedicam seu tempo e recursos em prol de uma única alternativa, deixando outras de lado e/ou ignorando os possíveis benefícios de suas complementariedades.

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Resumo

À luz do Plano Nacional de Resíduos (PNRS), Lei nº 12.305/10, ainda não colocado em prática e em revisão, o presente trabalho apresenta um modelo integrado de tratamento de resíduos sólidos urbanos em larga escala para a Região Metropolitana de São Paulo. A maior região macroeconômica brasileira se apresenta como típico caso de região atendida por aterros sanitários, porém, próximos do fim de suas vidas úteis. Com a maior densidade demográfica do país e rodeada por grandes reservatórios de água potável, a construção de novas áreas para disposição de resíduos não será tarefa fácil, sem que conte com o de acordo de outras regiões, órgãos de proteção ambiental e a gestão de maiores custos de transporte e disposição. Além disso, apesar da existência de iniciativas de coleta seletiva e reciclagem através de cooperativas de catadores subsidiados pelo Governo local, os resultados estão bem aquém do esperado.

A fim de quebrar o paradigma do investimento com baixo retorno atrativo quando se trata de iniciativas de saneamento básico, a tese sugere um modelo alternativo ao uso da terra e com foco fabril no reaproveitamento do lixo urbano. Apesar do alto investimento em tecnologias encontradas em países desenvolvidos, a consideração de receitas oriundas da reciclagem mecânica, biológica e térmica, com a produção e comercialização de eletricidade, mudam o patamar de retorno do investimento e com riscos muito baixos, segundo registros históricos.

Através de dados mais recentes da economia, foi simulado o impacto da proposta sobre a economia do ano de 2013 com um modelo insumo-produto de transações inter-regionais e intersetoriais. Considerada um novo setor na economia da RMSP, a proposta oferta reciclados (plástico, metal, papel, vidro, adubo orgânico e eletricidade) que substituem, segundo normas locais, os materiais virgens. Os impactos foram estimados através de variações do PIB, Valor de Produção, Postos de Trabalho, Consumo de Energia e Emissões de GHG em unidades de toneladas equivalentes de CO_2. Em síntese, haveria um crescimento no PIB e manutenção no valor da produção locais, porém, um decréscimo no resto do país em função do menor nível do valor dos reciclados em relação às matérias-primas virgens e mudanças na relação consumidor-fornecedor em todas as regiões. O número de postos de trabalho apresentaria uma elevação na RMSP, com uma leve queda no resto do país em função da natureza pronta do reciclado e sua capacidade substituir insumos brutos. A demanda energética cairia como consequência da introdução dos reciclados na cadeia produtiva. O tratamento térmico do resíduo remanescente reduziria a a necessidade de despacho de eletricidade oriunda da queima de combustíveis fósseis, onerosa e poluente. O nível de emissões de carbono também é reduzido com essa energia alternativa ao óleo e a mitigação de aterros sanitários que produzem CH_4.

A fim de contribuir com sucesso ainda não alcançado do PNRS e seu atual estágio de revisão, a tese faz uma crítica à política pública, apresentando um proposta de desafio mínimo para a reciclagem de materiais (plástico, papel e vidro) destinados ao mercado de descartáveis. O PNRS é uma ferramenta importante para a segurança jurídica para investimentos e implantação de iniciativas públicas e privadas, e precisa ser desafiado. Sem métricas e responsabilidades claras, seja qual for a política proposta para a gestão de resíduos urbanos, não terá sucesso mesmo com as melhores práticas mundiais, como por exemplo, o caso bem sucedido de destinação de pneumáticos no Brasil.

Abstract

Under the National Solid Waste Policy (PNRS), Law No.12.305/10, which is not working and now being reviewed, this study shows an integrated large-scale model of urban solid waste treatment for the Metropolitan Region of São Paulo. Most significant macroeconomic Brazilian region, it is the typical case of region attended by landfills, but all of them almost at the end of their lifetime. With the highest demographic density in the country and rounded by large drinkable water reservoirs, to build other areas to dispose of residues will not be an easy task without dealing with other regions, getting approval from environmental protection agencies, and managing higher costs of transportation and disposition. Besides that, even having initiatives of recyclables collection and recycling through collectors' cooperatives subsidized by local Government, their results are pretty low about what's expected to.

In a scenario of the low internal rate of return for essential sanitation enterprises, the thesis suggests an alternative model to the land use which is focused on an urban industrial waste recovering. Despite the high investment needed to use common well-recognized recycling technologies, the revenues from the sales of the products produced by mechanical, biological and thermal processes, including electricity, are the way to change the level of the interest rate of return with low risk, based on market parameters records.

Based on the most recent economic data, the thesis simulates the impact of the proposal on the 2013's economy through an interregional and intersectoral Input-Output (I-O) modeling. Through a new sector in the MRSP's economy, the project supplies recycled products (plastic, metal, paper, organic fertilizer and electricity) which can replace "virgin" ones, fitting requirements from local standards and procedures. The impacts on the economy have been estimated through calculated variations on GDP, the value of production, job positions, energy consumption and GHG emissions measured in equivalent tons of CO_2. Briefly, GDP would rise, and production valuation keeps the same in the MRSP, but decreasing in the rest of the country, due to the lowest value of the recyclables in comparison with "virgin" materials and changes in the relationship between consumer and supplier in all regions. The number of job positions would increase in the MRSP and slightly decrease in all regions explained by the ready-to-use nature of the recycled and its capacity of replacing new raw materials. The energy consumption would fall as a consequence of the recyclables' introduction in the production chain. Moreover, the remaining residues' thermal treatment would reduce the need for the dispatch of electricity produced by fossil fuels thermoelectric plants, expensive and polluting.

The level of carbon emissions would also decrease with this energy alternative to the oil-based and through the mitigation of landfills which release CH_4.

Contributing with success not yet achieved by the PNRS and its current stage of reviewing, the thesis also criticizes the public policy presenting a proposal of a minimum challenge for the materials recycling (plastic, paper, and glass) which are used to produce disposables. The PNRS is an essential tool of legal security for public and private investments and initiatives. Without clear metrics and responsibilities, independently of what it proposes as policy for the waste management, the success will not be achieved even considering worldwide best technologies and procedures, such as the successful benchmarking Brazilian case of pneumatics disposal.

Lista de Ilustrações

Lista de Tabelas

Lista de Abreviaturas e Siglas

3Rs – Reduce, Reuse and Recycle
ABAL – Associação Brasileira do Alumínio
ABIQUIM – Associação Brasileira da Indústria Química
ABIVIDRO – Associação Técnica Brasileira das Insdústrias Automáticas de Vidro
ABNT – Associação Brasileira de Normas Técnicas
ABRE – Associação Brasileira de Embalagem
ABRELPE – Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais
ABTCP – Associação Brasileira Técnica de Celulose e Papel
AC – Consumo Aparente
ANEEL – Agência Nacional de Energia Elétrica
ANIP – Associação Nacional da Indústria de Pneumáticos
ANVISA – Agência Nacional de Vigilância Sanitária
BACEN – Banco Central do Brasil
BEN – Balanço Energético Nacional
BNDES – Banco Nacional de Desenvolvimento Econômico e Social
CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CCEE – Câmara de Comercialização de Energia Elétrica
CEMPRE – Compromisso Empresarial para Reciclagem
CETESB – Companhia Ambiental do Estado de São Paulo
CH_4 – Gás Metano
CLT – Consolidação das Leis de Trabalho
CMU – Carnegie Mellon University
CNIM – Constructions industrielles de la Méditerranée
CO_2 – Gás Carbônico
CONAMA – Conselho Nacional de Meio Ambiente
COP 21 – 21^{st} Conference of the Parties to the UN Climate Change Conference
EEA – European Environmental Agency
EPA – Environmental Protection Agency
EPE – Empresa de Pesquisa Energética
EU 28 – 28 countries of the European Union
FEAM – Fundação Estadual do Meio Ambiente de Minas Gerais
GDP – Gross Domestic Product

GHG – Greenhouse Gas
HR – Human Resources
IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis
IBGE – Instituto Brasileiro de Geografia e Estatística
IEEP – Institute for European Environmental Policy
IMWM – Integrated Municipal Waste Management
I-O – Input-Output
IPEA – Instituto de Pesquisa Econômica Aplicada
IPCA – Índice Nacional de Preços ao Consumidor Amplo
IRR – Internal Rate of Return
LCV – Lower Calorific Value
MBT – Mechanical-Biological Treatment
MBT+WtE – Mechanical-Biological Treatment with Waste-to-Energy
MCTI – Ministério de Ciência, Tecnologia e Inovação
MEC – Ministério da Educação
MME – Ministério de Minas e Energia
MRSP – Metropolitan Region of São Paulo
MSW – Municipal Solid Waste
MSWM – Municipal Solid Waste Management
MW – Megawatt
NBR – Norma Brasileira
NOI - Net Operating Income
NPV – Net Present Value
O&M – Operations and Maintenance
OECD – Organization for Economic Co-operation and Development
PE – Polietileno
PET – Polietileno Tereftalato
PIB – Produto Interno Bruto
PNRS – Plano Nacional de Resíduos Sólidos
PNSB – Pesquisa Nacional de Saneamento Básico
PP – Polipropileno
PPA – Pollution and Prevention Act
PS – Poliestireno

PVC – Policloreto de Polivinila
RCRA – Resource, Conservation and Recovery Act
RDF – Refuse-Derived Fuel
RMSP – Região Metropolitana de São Paulo
ROE – Return on Equity
ROI – Return on Investment
SEEG – Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa
SEMASA – Serviço Municipal de Saneamento Ambiental de Santo André
TLP – Taxa de Juros de Longo Prazo
TWh – Terawatt-hora
UK – United Kingdom
UNICAMP – Universidade Estadual de Campinas
WACC – Weighted Average Cost of Capital
WIO – Waste Input-Output
WSUT – Waste Supply-Use Tables
WtE – Waste-to-Energy

Contents

INTRODUCTION

By the second report of The World Bank of 2012, the “What a Waste: A Global Review of Solid Waste Management” which has a vast amount of data about production and solid residues management, the world produces annually 1.3 billion metric tons of waste. That means 1.2 kg (or 2.7 lb) per habitant-day in locations with collection and waste disposal. About half of that comes from countries which belong to the Organization for Economic Co-operation and Development (OECD), composed of 34 nations. Outlooks are showing this scenario will increase to 2.2 billion metric tons by 2025 where China will lead a ranking of waste production with 63%, due to its production rise from 520 million to 1.4 billion metric tons. Currently, this ranking has the USA in the top with more than average 2.5 kg (or 5.5 lb) of waste produced by each person per day, as shown in **Figure 1**. Norway almost reaches this level through its citizens’ commitment. Italy is producing 89,000 metric tons daily, in average 2.2 kg (or 4.9 lb) per capita considering a population of 40 million people and should have a reduction by 2.8% in 2025 due to the recent period of unprecedented economic crisis (HOORNWEG and BHADA-TATA, 2012).

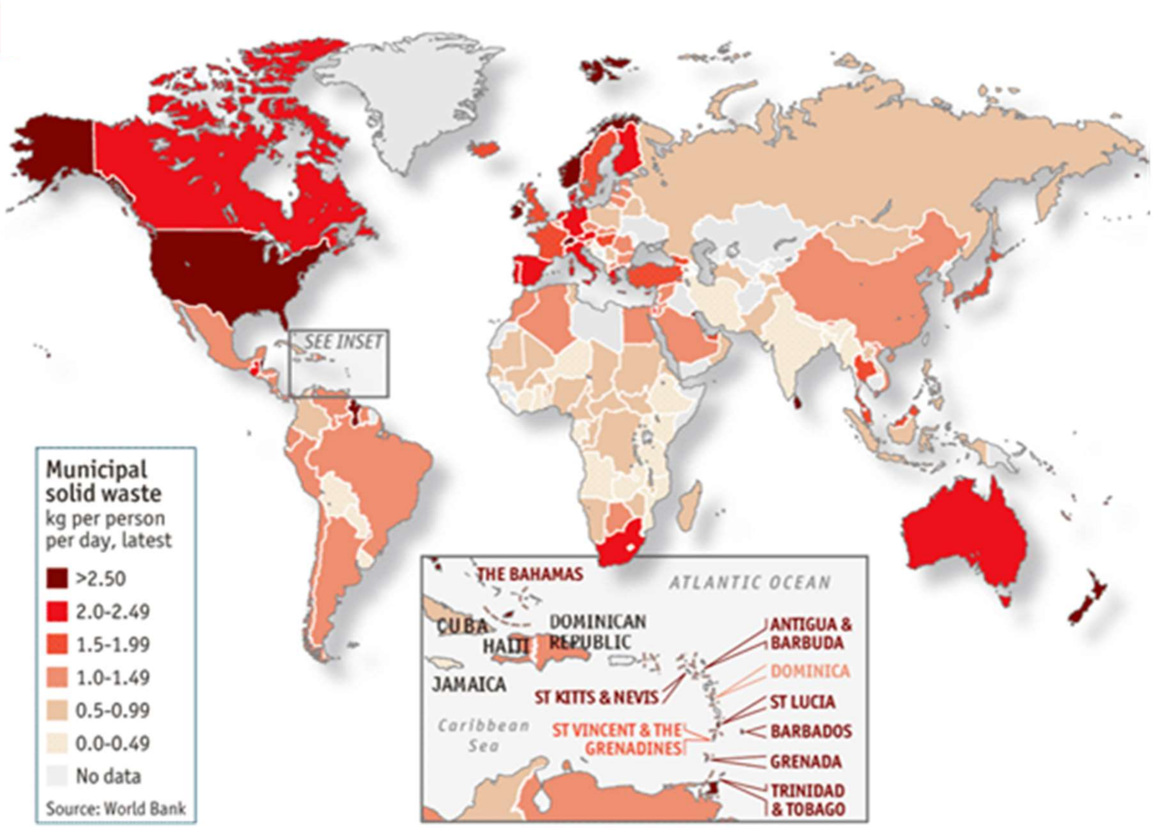

Figure 1. Urban Solid Waste generation in the world
Source: The World Bank (HOORNWEG and BHADA-TATA, 2012)

Important to remember that plenty of countries still not have a well-elaborated data control system and defined public policies, not mention a lack and incomplete statistics. Even so, if considered 1 kg (2.2 lb) produced by each person on average, there will be more than 7 million metric tons of waste daily to be managed in this planet by 2025.

Many countries have considered impact analysis and environmental cost-benefit models to check the economic viability in their studies for development, and this procedure has supported new guidelines, regulations, and laws to their public policies and governmental projects. A new vision of natural resources management has come, and this allows new levels of effectiveness and efficiency to be reached in all economic activities, respecting environmental diversity and stability. An example is the Empresa de Pesquisas Energéticas (EPE), a company under Brazil's Ministry of Mines and Energy (MME) in charge of several different scenarios (EPE; MME, 2018).

Figure 2 presents a panorama of how some countries around the world dispose of their urban solid wastes. A superficial analysis of this data takes us to the public policies applied to the sector in each nation, and to the straight direct relation between economic development and practices of waste recovery, such as landfilling, recycling, organic composting and high-temperature burning with energy recovery (or Waste-to-Energy).

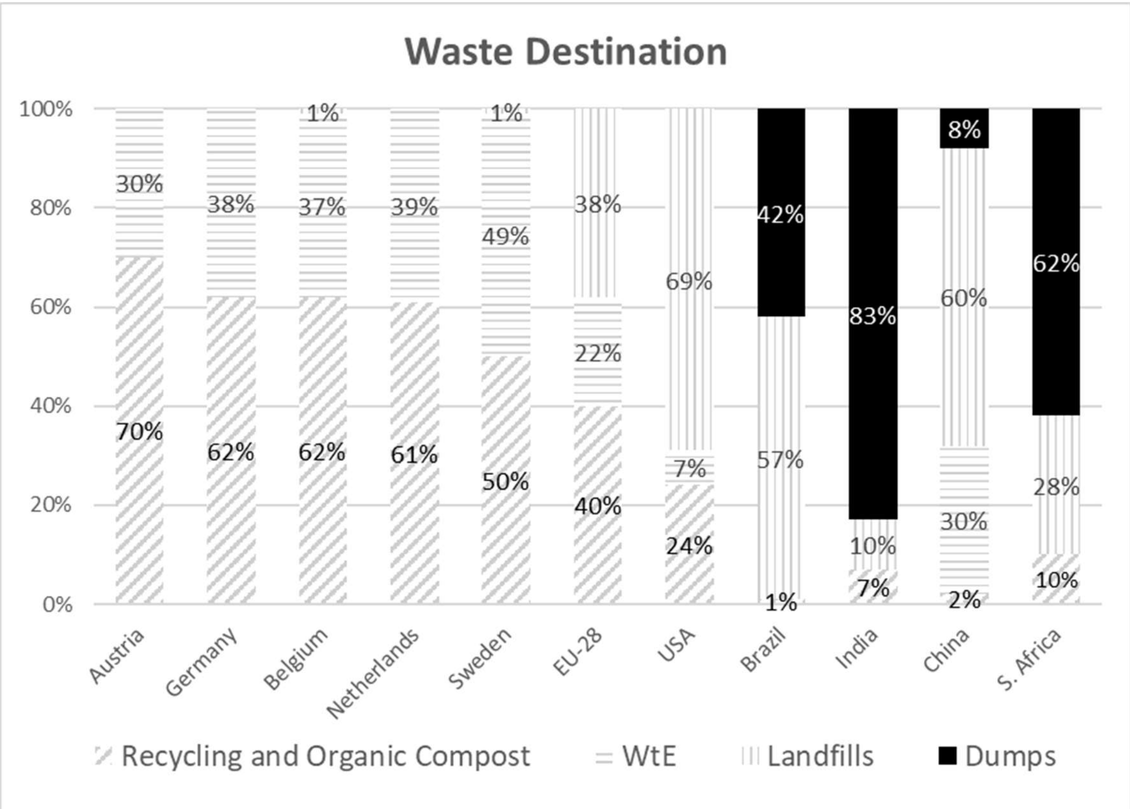

Figure 2. Final disposal of the urban solid waste in the world
Source: The World Bank (HOORNWEG and BHADA-TATA, 2012)

Brazil and most developing countries, where the land is the predominant way to treat their wastes, not only environmental issues have been difficult to solve due to poor solid waste management. Vectors of disease transmission are proliferating, and greenhouse gases releases have gotten worse the global warming effects when most of the waste, especially the organic fraction, has been disposed in landfills, or most of the worst cases, under dumps conditions (HAKAMI, 2016).

Level of developing and waste generation seems to have a very close relation. As shown in **Figure 3**, developing countries like Brazil and India present an increase in their waste production when their gross domestic product (GDP) not even have a significant growth to stimulate consumption.

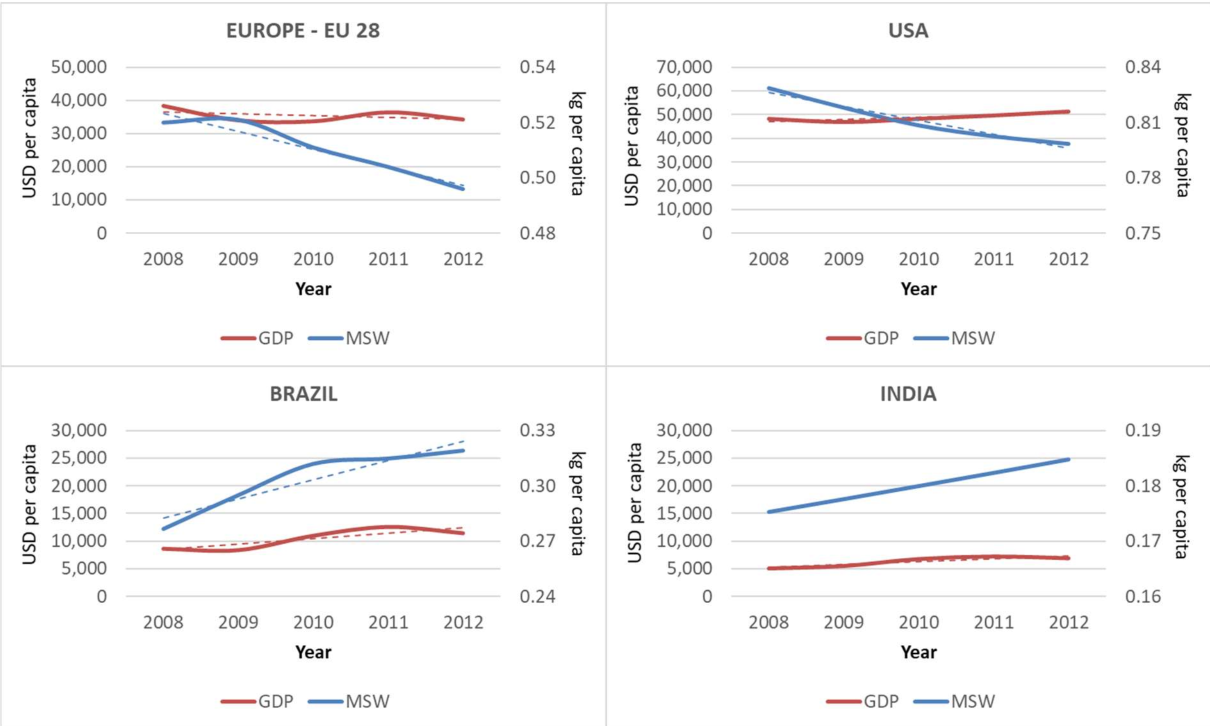

Figure 3. Relation GDP and MSW generation in developed and developing regions
Adapted from: The World Bank (HOORNWEG and BHADA-TATA, 2012) and IBGE (IBGE, 2013)

On the other hand, countries or developed continents, such as the USA and Europe, have shown a decrease in a waste generation when their GDP remains practically flat. The World Bank's reports explain that based on public policies for responsible consumption and disposal adopted by these regions. By the way, in developing countries, where public policies seem to be poor or not even exist, Governments are promoting the politics of income distribution trying to reduce social differences. These popular politics without well-established waste management encourage consumption and disposal, also when the economy appears to be flat (HOORNWEG and BHADA-TATA, 2012).

As shown in **Figure 4**, from 2003 to 2016, the amount of urban waste shows a better correlation with GDP, despite periods delay. In this interval of time, the Brazilian MSW raised 26.4% while its GDP incremented in 33.6%.

In the last six years was noticed by ABRELPE (ABRELPE, 2016) and IBGE (IBGE, 2013) the amount of MSW generated in Brazil increased 16.4%, what it is pretty higher than population (+7.4%) and GDP (+9.6%) growth.

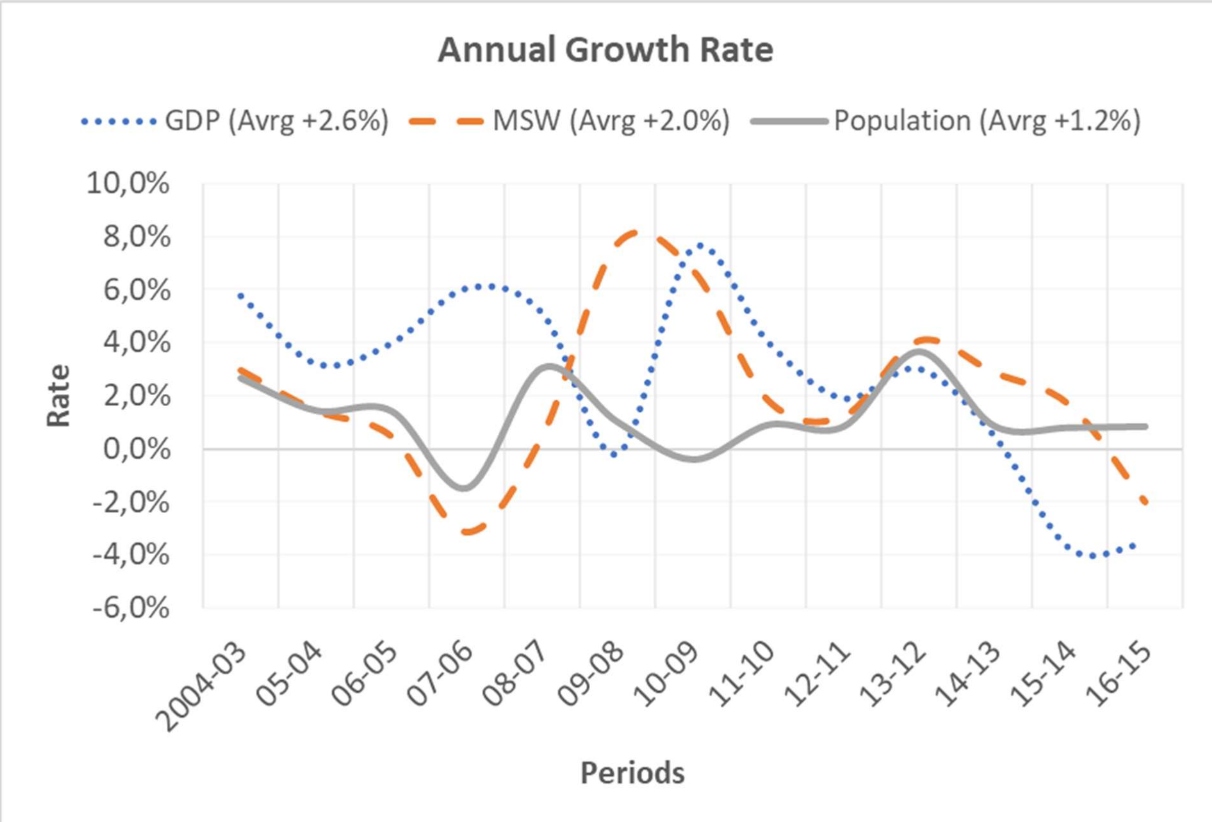

Figure 4. MSW generation in Brazil from 2003 to 2016
Source: ABRELPE (ABRELPE, 2016) and IBGE (IBGE, 2013)

The low effectiveness of the Brazilian Municipal Solid Waste Management (MSWM) is evident if compared to developed countries' ones. In the Netherlands, where 39% of its waste has mechanical recycling, 7% is biologically treated to get organic fertilizer, 42% is thermally treated to recover energy, and only 12% reaches the landfills (HOORNWEG and BHADA-TATA, 2012).

By the Brazilian Institute of Geography and Statistics (IBGE**)** and its National Research of Basic Sanitation **(**PNSB**)**, 99.96% of the cities have waste collection service, but 50.75%

reaches the dumps[1], 22.54% the controlled landfills[2] and 27.68% the landfills[3] (IBGE, 2013). These same data reports that only 3.79% of the cities have units to treat organics, 11.56% have a recyclables collection and mechanical treatment, and 0.61% have landfill gas recovery. In this last case, considering the energy recovery through landfills gas, Brazil has 13 biogas plants which are burning gas produced by landfills or anaerobic reactors and adding 70MW of electricity, or 0.06%, to the national energy matrix (ANEEL, 2011; SANTOS et al., 2016).

The practice of disposing of waste in non-recommended areas, or dumps, causes severe and damaging consequences to the public health and environment, and contribute to the degraded socioeconomic picture. Too many families are surviving in subhuman conditions through what they pick from dumps, like the rest of foods and recyclables sold, as shown in **Figure 5**. By IPEA, there are more than 400 thousand solid residues collectors "working" in Brazilian dumps. If considering all family members, this number rises to more than 1.4 million people surviving through to the urban waste. Despite this degraded condition of work, where people are facing imminent risk to their health and security, almost 50% of these people, "working" in 5,570 Brazilian cities, can get up to 1 minimum wage per month selling what they get from the waste (IPEA, 2012).

Taking as reference Switzerland withing its 41.3 thousand km^2 (or 159.5 thousand mi^2) and, approximately, 8 million people, where the high demographic density (194 people per km^2 or 50 people per mi^2) justifies to intensify recycling and the Waste-to-Energy practice. Then, it is essential to ask: Why is there not a similar practice in the Metropolitan Region of São Paulo (MRSP), where the demographic density is 2,447 people per km^2 (or 630 people per mi^2), considering its total area of 8.5 thousand km^2 (or 32.8 thousand mi^2) and a population of 20.8 million people? In this area, the MRSP produces daily 0.8 kg (or 1.8 lb) per capita, or another perspective, 1,958 kg of residues per km^2 (or 11,180 lb of residues per mi^2). Switzerland produces a maximum of 484 kg of residues per km^2 (or 2,764 lb of residues per mi^2), which

[1] **Dumps** are open-air deposits of urban waste, well-known in Brazil as "vazadouros", "lixeiras", or "lixões". They are areas where urban waste is disposed without any land protection to avoid ground and water contamination. In these systems there's no treatment for liquid effluents – slurry (or "chorume" in Brazil) is the liquid produced from the organic waste under decomposition. As a consequence, this liquid penetrates in to the land taking contaminants to the ground and water sources.

[2] **Controlled landfills** mean an intermediate category between dumps and landfills. Normally they're a cell near a dump, an attempted to improve it using a green coverage (e.g. grass) and clay to avoid ground contamination and support any movement.

[3] **Landfills** are considered adequate to dispose urban solid waste using the land. Their main characteristic is the procedure of using mats of plastic to prevent of slurry contamination. Drains and flares are built to take the slurry to treatment's reservoirs, and to release gases that can be simply burnt and/or piped to energy plants.

means 2.5 kg (or 5.5 lb) per capita-day in this country by The World Bank (BESEN et al., 2014; HOORNWEG and BHADA-TATA, 2012).

Figure 5. People collecting recyclables and rest of food in Brazilian dumps

The current institutional scenario is pretty adverse, even launching the National Solid Waste Policy (PNRS) through the Law No.12.305 in 2010, due to slowness actions and political negligence with environmental issues and too much pressure from industry segments who try to avoid the polluter-pays principle and its implications (BRASIL, 2011). Most municipalities do not have technical and financial resources to solve problems related to solid residues management yet. Planning and costs are the most significant problems which inhibit recycling's growth and expansion (CEMPRE, 2013). There are low penetration and incentives for other technologies to treat the rest of the waste except mechanical recycling or biological treatment. The main reasons are few (or none) lines of funding to invest in sanitary services, a poor public policy not mentioning alternatives to the landfills and not challenging levels of recycling, and decision-makers with a low level of information about new technologies, but full of ideologism (ROSA and TOMALSQUIM, 2003). An example comes from the Waste-to-Energy technology which faces resistance from environmental entities still trying to compare it with incineration (low temperature, low time of residence of gases without filters and dioxins emissions), and recycling cooperatives are refusing it with the argument of destroying social value when burning recyclables (AIDIS, 2006).

Giving this chaotic scenario of accelerated generation of MSW and a lack of practical actions to manage the problem, this thesis comes to:

A. MAIN OBJECTIVE:

i. *Show the Economic Viability of a Large-Scale Integrated Model of MSW Treatment at the Metropolitan Region of São Paulo based on existing waste recovery technologies; and*

ii. *Present its Socioeconomic, Energetic and Carbon Impacts if treating all its municipal solid waste.*

B. SECONDARY OBJECTIVE:

i. *Propose a Methodology to Calculate a Minimum Recycling Rate for Disposals which could be useful to the National Solid Waste Policy (PNRS).*

All the model has analyzed considering almost 20-year market records feeding economic and risk calculations, and most recent waste characterization data for the waste in the MRSP has been used to check the regional and interregional impacts through an Input-Output (I-O) modeling.

Addressed within all the issues as detailed as possible, the thesis begins with **CHAPTER 1**. Here, essential concepts about waste are shown based on standards and best practices known. The current PNRS is detailed and followed by the situation of the MRSP with a literature review to explain what's going on regarding urban waste treatment integrated large-scale initiatives in Brazil and the world.

CHAPTER 2 brings used methodologies and their hypothesis for the economic viability analysis and its risk, the I-O interregional modeling impacting the economy with recyclables, energy, and carbon associated to the production, and a benchmarking case to challenge the current PNRS.

Results and discussions are in **CHAPTER 3**, where sources of revenues, expenses and value generation are calculated based on the past ten years of records to offer a robust risk analysis. Through the I-O modeling are shown regional and interregional impacts on GDP, production value, number of jobs, energy consumption and carbon emissions, if the economy receives recyclables, organic fertilizer and energy from this proposed model of municipal waste treatment in the MRSP. In this chapter, it is possible to verify the importance of recycling to reduce energy demand with a source of electricity alternative to the dispatch of fuel oil-based one with less carbon release. Additionally, this chapter presents what would be minimum rates of recycling for disposables, such as plastic, glass, and paper, mobilizing the Brazilian society to achieve these results.

Finally, **CHAPTER 4** presents conclusions addressing to answer if it is economically viable to build a large-scale model of urban waste treatment at MRSP and what would be its impacts to the economy of the own region and the rest of Brazil. Challenging the current public policy, would it be an encouraging a way to improve the municipal solid waste management in Brazil substantially?

As future research, the author proposes a similar study to understand what would be the national public budget, socioeconomic, energy and carbon emissions impacts if considered all ten most significant metropolitan regions where are living more than 25% of the citizens producing almost 60% of all Brazilian urban waste. Another critical challenge would be a proposal to create a mechanism to stimulate a minimum rate of organic composting, once organics are almost 60% of the total amount of waste produced in Brazil.

CHAPTER 1. CONCEPTS, NATIONAL POLICY, METROPOLITAN REGION OF SÃO PAULO AND LITERATURE REVIEW

In this chapter are presented terms, concepts and the state-of-art for the MSWM in Brazil, detailing the current situation in its most important economic region. These contents are essential to delimit what kind of waste this thesis is studying and, understand the status of the national policy showing what's going on at MRSP, clearly indicates the importance of the theme.

Most important initiatives about MSWM were researched in the literature and listed to support the arguments throughout the text and to evidence the originality of the work for the MRSP.

1.1 IMPORTANT CONCEPTS ABOUT RESIDUES

Initially, it is essential to define the concept about solid residues, or semi-solid residues, like those which are the results of the community activities and their several sources, such as industrial, domestic, hospital, commercial, agriculture, services and urban sweeping. The sludge that comes from the water and sewage treatment facilities, particulates from air pollution control equipment and installations, or any solid, and even liquid, not allowed to dispose of into the public system complex, is under standard control. Everything that demands any kind of technical solution, economically viable or not, is solid residue according to ABNT NBR 10.004/2004 (ABNT, 2004).

The Urban Residues, or Municipal Residues, are generated in the urban areas, while the Special ones come from transformation processes (see **Table 1.1.1**). These last ones need special attention in collecting, packaging, transportation, manipulation, and disposal, due to their peculiar characteristics.

Table 1.1.1. Solid Residues classification according to their origins

CLASSIFICATION	ORIGIN
URBAN RESIDUES	*Residences, commercial activities, city sweeping and landscape services (e.g., tree pruning and gardening).*
SPECIAL RESIDUES	*Transformation processes, such as industrial, agricultural, radioactive, health services and building.*

Source: Brazilian standard NBR 10.004/2004 (ABNT, 2004)

Another classification of the residues is by their ecological, sanitary, economic and physical aspects (see **Table 1.1.2**).

Table 1.1.2. Solid Residues classification based on their physical characteristics

RESIDUES	DESCRIPTION
CLASS I (Hazardous materials)	*Characteristics of toxicity, flammability, corrosivity, reactivity, radioactivity, and pathogenicity which may offer risk to the public health or adverse effects on the environment.*
CLASS II A (Non-inert materials)	*Materials who do not fit what is described by CLASS I (Hazardous materials) and CLASS II B (Inert materials). The residues belonging to this class can have these properties: biodegradability, combustibility or solubility in water.*
CLASS II B (Inert materials)	*Materials not soluble or those who do not have any soluble component within higher concentrations established by the standard (NBR 10.006 – Solubilization of Residues)*

Source: Brazilian standard NBR 10.004/2004 (ABNT, 2004)

The characteristics of residues may vary, by ZANTA and FERREIRA, due to factors which make a distinction between communities, such as social, economic, cultural, geographic and climatic, besides biological and chemical aspects. It is essential to know and understand these characteristics to choose the most appropriate process and technique of waste disposal and treatment.

Other relevant data to take into account is the gravimetric composition. The waste management must attend what kind of materials is in the mass, as categorized in **Table 1.1.3**. It is a must to make specific the level of humidity, once organics are a wet phase and the other materials (i.e., plastic, glass, paper, and metal) are dry ones (ZANTA and FERREIRA, 2003).

Table 1.1.3. Categories and examples of the urban solid residues

CATEGORY	EXAMPLES
Organic material	*Rest of food, flowers, grass and pruned trees.*
Plastic	*Sacks, bags, packages of milk, water, and other beverages, cleaning, cosmetics, food containers, sponges, Styrofoam, kitchen appliances, latex, raffia bags.*
Paper e cardboard	*Boxes, magazines, journals, cards, paper, plates, cups, books, notebooks, folders, napkins.*
Glass	*Cups, bottles, plates, mirrors, containers for cleaning, makeup, body care, and food.*
Ferrous metal	*Steel wool, pins, needles, container's foods.*
Non-ferrous metal	*Beverages' cans, electric wires (copper, aluminum).*
Wood	*Boxes, planks, sticks, matches, furniture, firewood.*
Cloths, rags, leather, and rubber	*Clothes, cleaning cloths, pieces of clothes, bags, back packages, shoes, carpets, gloves, belts, balloons.*
Chemical contaminant	*Batteries, medicines, lamps, insecticides, rat poisons, glues in general, cosmetics, pressurized containers, pens, carbon paper, photographic plastic film bases.*
Biological contaminant	*Toilet paper, cotton swab, cotton, bandages, cloths with blood, disposable diapers, sanitary napkins, syringes, shaving blades, hair, gloves.*
Rock, soil, and ceramic	*Vases of flowers, plates, rest of materials used in buildings, soil, bricks, rocks.*
Others	*Wax candles, rest of soap, charcoal, butts of the cigar, credit cards, stoppers, wax pencils, long-life packages, metal-covered packages, dust bags, clothes and grinding paper or discs, and materials hard to identify.*

Source: (PESSIN and Al., 2006)

The MSW is a type of residue particularly challenging to manage due to its heterogeneous composition, varying too much and dependent on the region where it is. Amount and composition generally depend on the population habits, culture and, mainly, to its level of economic development, what all together bring a high level of complexity to solve the problem.

So, to get feasible solutions, it is more than necessary the knowledge of current technologies and their possible connections with the MSW composition (EDJABOU et al., 2015).

Waste content and level of economic development of the producer area are the main variables to be analyzed to propose economic viable, socially fair and politically acceptable solutions.

1.2 CURRENT NATIONAL SOLID WASTE POLICY

The Law No.12.305/10 established in 2010 demands a set of rules to support the management of solid waste in Brazil. It presents a hierarchy of activities, such as Reverse Logistics, Recycling, and Final Waste Disposable. Also sets the figure of shared responsibility where residues producers (manufacturers, importers, distributors, traders, and consumers), sanitary services' entrepreneurs and government must work in consonance, in accordance with Federal Environment Ministry (BRASIL, 2011).

The first movement to guide residues management in Brazil was noticed in 1991 with the Law Project No.203 where packaging, collection, transport, and destination were discussed to cover the health sector.

In 1999 CONAMA's proposition No.209 was taken to the Congress of deputies. Technical directives to solid residues management were approved but not published.

Three years later, in 2001, deputies created and implemented a special commission to a national residues' policy. The idea was to adopt practices from the Law's Project No.203/91 and extend them to other sectors (ROLLEMBERG, 1991). However, this commission interrupted their jobs without concluding the objective at the end of legislation. In the same year, it was possible to watch the first social movement, with 3,000 participants, called the 1st Congress of Recyclables' Collectors. Specialists, members of Congress and mainly, homeless people, were addressing for waste as an alternative to income.

Later in 2003, the 1st Latin-American Congress of Collectors discussed professional training needs, dumps eradication and the responsibility of the residues producers. Due to this, it was created, by the Federal Government, the Interministerial Group of Environmental Sanitation which resulted in the Urban Solid Residues Program. In the same year, it was realized the 1st Conference of Environment in Brazil.

From 2004 to 2009, all initiatives were managed by Environment Ministry who involved other ministries, economy's sectors, associations and politics to get contributions to format a policy. During this period, it was seen the social aspect taking the place of the environmental one. As mentioned in the PNRS's final text: "Waste destination and treatment were not the final reason to establish a national policy but the way to create and distribute income to the poorest people working informally in the cooperatives of recyclables' collectors" (AMBIENTE, 2018).

Published and working from 2010, the PNRS presented some challenges and goals to achieve:

- Recyclables collection with organic composting in 100% of Brazilian cities
- Achieve a recycling rate of 20% by 2015
- Eradication of dumps by 2014
- Achieve 22% of recovering products (e.g., plastic vessels for chemicals, tires) through Reverse Logistics

Already used in 2003, the interministerial committee was restored in 2011 to monitor the evolution of the plan. This committee was responsible for establishing the policy in all national territory, and its tasks are:

- Review
- Monitor
- Encourage
- Discuss

This group and specialists, led by the Ministry of Environment, started to review the PNRS in Jan./2017 and planned to finish it in 20 months, or up to Sep./2018. Moreover, it seems to be an excellent opportunity to review it with updated aspects. Reverse logistics, such as new environmental legal requirements, social and corporate responsibilities, sustainability versus competitiveness, activities and their activities' sequences, all applied to post-consumption recycling must be taking into account as detailed in AGRAWAL's article (AGRAWAL et al., 2015).

Looking at waste management activities developed by the USA and Germany, as a European's representative, what calls most attention are how long they take and the strategies that have chosen.

In USA's case is found the creation of the RCRA (Resource Conservation and Recovery Act) in 1976 by the Congress (EPA, 1976). This act has been the most important movement to establish the mechanisms for waste destination and treatment. After that, US government created the PPA (Pollution and Prevention Act) in 1990 who formally put EPA (Environmental Protection Agency) in charge of monitoring challenges and goals defined by this last act (EPA, 1990).

Germany started earlier and since the 1920s discussing waste as a source of raw materials and energy. It was the first country in the EU to introduce producer responsibility with a packaging waste regulation in 1991 (EU, 1991). According to this principle, which is a core tenet of German waste legislation, the producer of a product is generally responsible for the product when it becomes waste. Twenty European countries are using a landfill tax, but this does not include Germany. Germany has a very high level of recycling of MSW, and it is interesting that Germany has achieved this without using a landfill tax. The requirement of pre-treatment of MSW before disposing of it in landfills combined with other management activities such as producer responsibility have been strong drivers in diverting MSW away from landfills and towards recycling.

Brazilian's waste management has a well succeed initiative of treating post-consumed residues where producers are responsible for their treatment, just as postulated by Germans. In case of tires, there is a resolution from CONAMA (National Council of Environment), a collegiate organism in the Ministry of Environment, No.258/99 which established the goal of 1 tire recycled per each one produced (CONAMA, 1999). In this act, producers are in charge of collecting and recycling, but users are responsible for leaving them in the collection points. Moreover, as Americans have done, the Brazilian Government has created a resolution to track and control these activities. Through CONAMA No.416/09 is possible to identify what is responsibility from local producers, importers and IBAMA (Institute of Environment and Renewable Natural Resources) has been designated to monitor the statistics and apply penalties when necessary, similar to what EPA has done in USA (CONAMA, 2009).

As a result of this measures, the level of recycling for tires in Brazil is not lower than 80%. Considering only local producers, this is pretty much higher than the initial target of 100% fixed to collection points in cities with more than 100,000 people. This amount would represent 29% of total municipalities, or 60% of cities with more than 20,000 citizens (almost 50% of Brazilian municipalities), as shown in **Figure 1.2.1** and **Figure 1.2.2**.

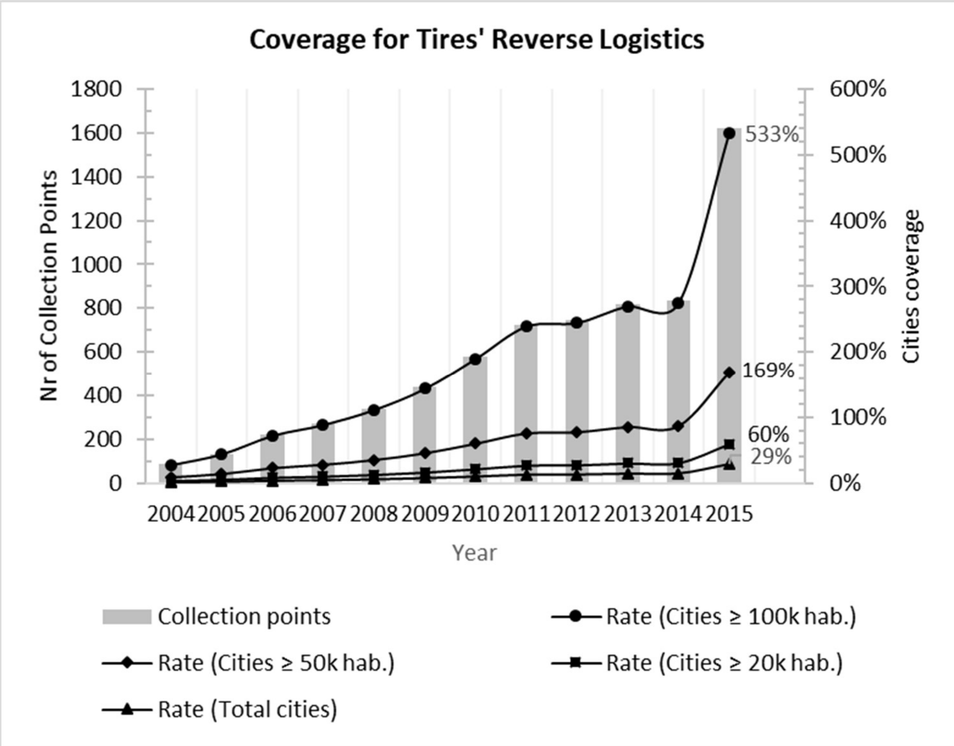

Figure 1.2.1. Collection coverage for Tires
Source: Data compilation from ANIP (MARRONE and Al., 2015) and IBAMA (IBAMA, 2016)

Reacting to this remaining passive of 18% (see **Figure 1.2.2**), caused by importers who are not recycling as requested, one of the mechanisms used to force importers to recover is raising the import tax. Another one is to limit the number of the import quota.

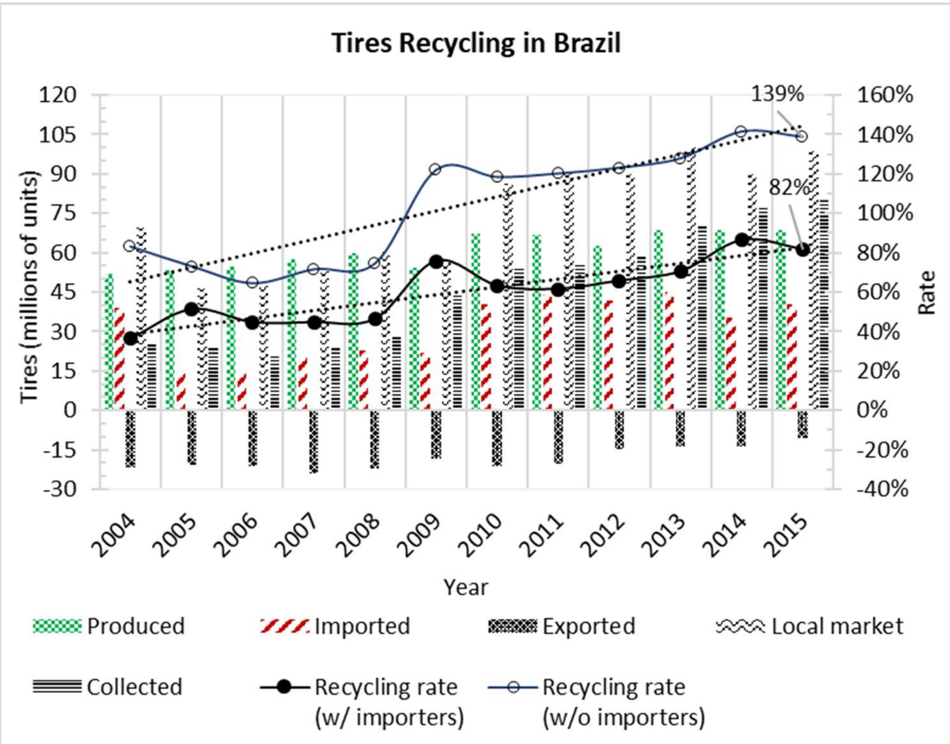

Figure 1.2.2. Tires Recycling in Brazil
Source: Data compilation from ANIP (MARRONE and Al., 2015) and IBAMA (IBAMA, 2016)

However, what are producers doing to recycle as much as the law requires once recycling could represent value destruction in the production chain? The answer is in **Figure 1.2.3** below, where the tire's cycle of production and destination's breakdown is shown in image and numbers, respectively.

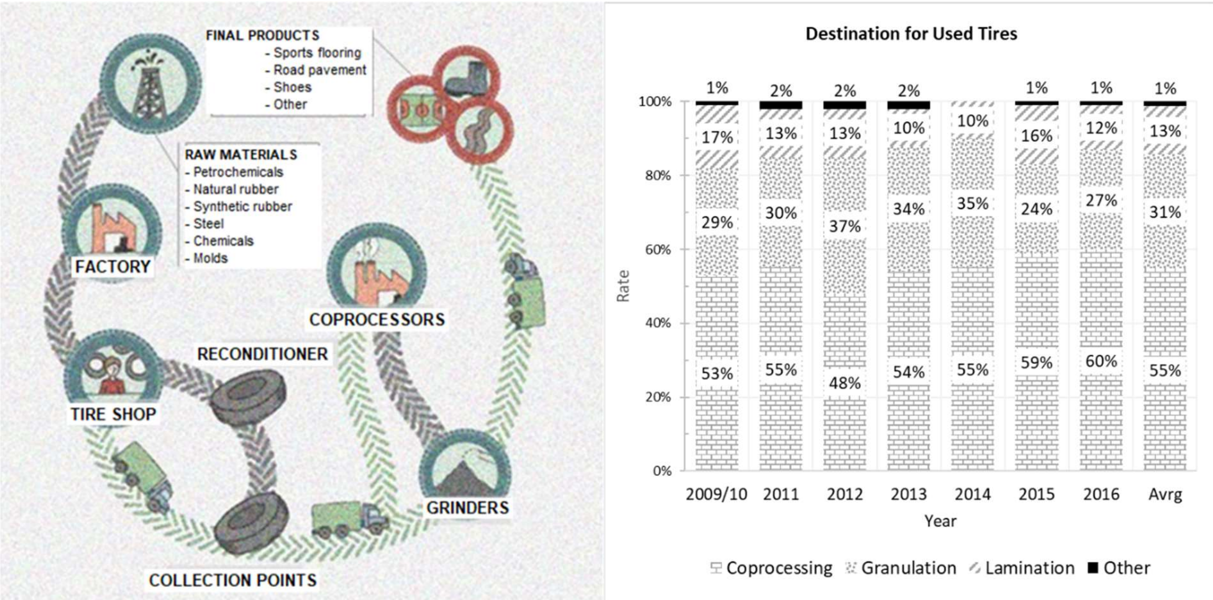

Figure 1.2.3. Life Cycle and Final Destination for Used Tires
Source: Data compilation from ANIP (MARRONE and Al., 2015) and IBAMA (IBAMA, 2016)

In summary, producers quickly have transformed expenses in revenues when developing applications and markets for products from discarded tires. Almost 60% is now used by the cement industry, reducing fossil fuel demand. Nearly 27% is granulated to use in the pavement (concrete or asphalt), 12% used to produce rubber mats and 1% used in the shale industry, pyrolysis and other more. However, never being used to compete with new tires.

Another recognized initiative done by the government was the normative CONAMA No.452/12 which prohibits used tires imports whatever the application (CONAMA, 2012).

1.3 WASTE AT METROPOLITAN REGION OF SÃO PAULO

The Metropolitan Region of São Paulo (MRSP) is the biggest wealth generation center in Brazil. This macro-region holds a large part of the national private capital with the most important industrial complexes, commercial and financial headquarters installed and responsible for the Brazilian economic activity. It represents 56% of São Paulo state´s GDP and 20% of Brazil´s one. Its GDP per capita is 1.7 times bigger than country´s one, by the Brazilian

Institute of Geography and Statistics (IBGE) and São Paulo State Foundation for Statistics (SEADE) (IBGE, 2013; SEADE, 2011).

Directly associated with value and income generation, the amount of Municipal Solid Waste (MSW) is equally high in this Brazilian region. The MRSP has São Paulo city, the capital of São Paulo state, with 11 million people, considered the largest of Brazil and one of the largest worldwide urban agglomerations. With 39 cities, this region produces 21.4 thousand metric tons per day or annually 7.7 million metric tons of MSW in 2013. This amount corresponds to 10% of all Brazilian's MSW, and only São Paulo city contributes 62.5% at MRSP (ABRELPE, 2014; IBGE, 2013).

The absence of an Integrated Municipal Waste Management (IMWM) is one of the factors responsible for hindering the coordination of an integrated action between municipalities, and that is why environmental and financial costs are too high in this region. As for the household garbage collection in the urban area, only five municipalities have less than 90% coverage in the MRSP. On disposal, approximately half of the total cities have their wastes in landfills, and the other half in controlled landfills (**Figure A 1**), what partially attends the Brazilian PNRS (National Policy for Solid Waste) (BRASIL, 2011; FUNASA, 2010).

In the MRSP, as well as in the city of São Paulo, the average urban waste generation per capita is about 1 kg per day. The significant difference between MRSP and other Brazilian macro-regions, concerning waste disposal, is the dumps' eradication as requested by the PNRS. The number of municipalities who disposal their wastes in landfills out their limits increased from 23 in 2005 to 32 in 2009 (JACOBI and BESEN, 2011).

In 2010, 29 cities from MRSP (74.4%) had a recyclables collection, but only seven of them had 100% urban area coverage. In 28 of them, recyclables' collectors worked organized in cooperatives subsidized by the governments. With 2,206 collectors, this recyclables collection covered 28 municipalities with 1,045 people in São Paulo city and 1,161 ones shared with the other 27 cities (**Figure A 2**). However, these cooperatives have shown low efficiency, because 70 to 80% of all recyclables collected are still coming from the informal collectors working under precarious conditions in the streets of the cities (BESEN et al., 2014; JACOBI and BESEN, 2011).

In a financial point of view, São Paulo's recyclables collection has cost R$ 192 (or USD 79) per metric ton, or the equivalent to R$ 8.3 million (or USD 3.4 million) per year. This cost represented a little bit more than 1% expended in 2013 (R$ 725 million or USD 298 million) to collect, transport and dispose of MSW in landfills and dumps, but it was twice higher than the conventional process (CEMPRE, 2013).

Most recent information from São Paulo's Municipal Secretary of Services presents 31 collectors' cooperatives working in the city with 3.2 thousand collectors, and despite having 10% as an agreed target to the recycling, no more than 4% of the MSW is recovered (CEMPRE, 2013; JACOBI and BESEN, 2011). Other important information comes from the infrastructure available to the recyclables collection. Only 7% of the waste collection fleet, working under contract in São Paulo, is available to support the recyclables collection. This inefficient recyclables' collection and its low coverage in São Paulo causes economic losses estimated at R$ 749 million (or USD 308 million) per year. More than 1 million ton of paper, plastic, metal, and glass are discarded and transported to landfills, instead of sorted and sold to return to the production chains (BIZZOTTO, 2010).

Less waste recovered means to reduce the landfills lifetime in the region with too many restrictions to build new ones. More than 50% of the MRSP is environmentally under protection due to water reservoirs. Programs for reducing the traffic and gas emissions in the transportation, high freight costs and disposal far from the point of waste generation are primary reasons that make tough to build new disposal areas (ZHANG et al., 2010).

1.4 LITERATURE REVIEW

This MRSP's scenario shown above is typical in the world. Authors, such as ZHANG and RUOFEI, report about sharp population growth in China and its residues' generation without appropriate treatment. The solution to the problem, as well as the majority articles found to developing countries, is to replicate well-succeed European cases, especially Danishes MSWM's models (RUOFEI and SIBEI, 2010; ZHANG et al., 2010). This task seems to be simple and trivial if it was not by the fact Denmark's GDP is three times bigger than MRSP's one, and five times higher than Brazilian's one. It is one of the six European nations, which has at least 90% of its MSW destined to save and generate energy through a recyclables collection to recycle metals, glass, paper and plastic, organic compost and incinerating waste to produce electricity and steam for heating. In these developed countries, there is an awareness culture of environmental impact mitigation based on conscious consumption through the 3Rs (Reduce, Reuse and Recycle). There is a clear understanding, in all mentioned references, waste is a public health problem, and due to this, governments do not save investments to get solutions avoiding land-use, mainly because, in most of the cases, there is not its availability in Europe.

Most recent articles are coming with a new approach: procedures and technologies should complement each other to improve the sustainability on waste treatment, mainly when the focus is to reach economic viability and mitigation of environmental impacts. CIMPAN presents in his study that it is possible to get an expressive reduction of CO_2 emissions and high net profits, in comparison with landfills, when applying the WtE after the MBT one. The explanation comes from an improved Refuse-Derived Fuel (RDF) with a higher Lower Calorific Value (LCV). Due to only "clean" recyclables (metal, plastic, paper, and glass) and all wet portion (organics) are sorted, what remains is a mass with enough "dirty" plastic and paper which are not feasible to be cleaned and commercialized (CIMPAN and WENZEL, 2013).

HAM also suggests a combination of technologies in his Korean article for sustainable solid waste management. The author calls attention to the efficiency improvement when associating techniques and, emphasizes that less amount of waste to be burn reduce WtE facility's scale, what is extremely important to let the business model less capital intensive and more viable (HAM and LEE, 2017).

WHEELER, from the Waste Management Magazine and KHALID, have written scientific texts where both reinforced the importance of the technologies' complementarity and called attention to the potential of energy generation if considered anaerobic digestion in the MBT (KHALID et al., 2011; WHEELER, 2006). The author WHEELER has estimated up to 15% of the UK's energy demand could be supplied by its biological anaerobic digestion. The same magazine published in 2013 a text informing a proposed £ 240 million small-scale waste facility is featuring MBT+WtE with 245 thousand metric tons per year (or about 0.5% of the annual production of waste) and 14 MW of capacity (WEKA, 2013). By the same authors, the urban waste anaerobic bio-digestion is not very common on the industrial scale except when considering wastewater treatment. That is because the MSW presents low-efficiency anaerobic digestion and business economic viability when compared with bio-digestion of sewage sludge, agriculture, and livestock residues. The heterogeneous composition of the urban organic waste and the presence of stabilizers and acidulants retard the anaerobic bio-digestion in the reactors. So, the best way to get methane from MSW anaerobic digestion is still in landfills where waste amount, degradation and pressure build-up are the matters of space and time.

Pioneer simulating environmental impacts through input-output (I-O) models, LEONTIEF has inspired too many scientific works on waste management (LEONTIEF, 1986). NAKAMURA and KONDO have estimated a waste input-output (WIO) table for Japan and applied it to evaluating the effects of alternative waste management. They have found that concentrating treatment in a small number of large incinerators, combined with an increased degree of sorting, could decrease both landfill usage and CO_2 emissions (NAKAMURA and KONDO, 2002). LENZEN and REYNOLDS extended WIO, incorporating a supply-use routine, resulting in waste supply-use tables (WSUTs) in 2014. They presented the theoretical underpinnings of the WSUT calculus using economic and waste data for the Australian economy in 2008–2009 (LENZEN and REYNOLDS, 2014).

Some Brazilian works and authors do not present an integration of existing technologies for MSW treatment in the light of sustainability. SANTOS (SANTOS, 2011) discusses landfills and incinerators, LIMA (LIMA, 2012), describes technological alternatives to several regions in the country, and even VIEIRA (VIEIRA, 2011) writes about electricity considering all the urban waste, but neglecting mechanical recycling and composting. PIMENTEIRA shows preliminary analyzes taking into account socioeconomic aspects of Rio de Janeiro's MSWM. In his dissertation, an I-O model was used to verify the impacts and effects of recyclable materials in the economy (PIMENTEIRA, 2002). After eight years, the same author presented his doctoral thesis, complementing the dissertation with the I-O model analyzing the impact of MSWM policy at Rio de Janeiro's government and its economy (PIMENTEIRA, 2010). However, in both studies, the author has not considered building an integrated plant to treat 100% of the RSU and neither its economic viability. He has considered integrating current initiatives as a way to get financial and social benefits to the economy of Rio de Janeiro and, pointed out high costs to the society if proposed another mechanism to treat MSW, such as WtE plants.

CHAPTER 2. METHODOLOGY AND CONSIDERATIONS

2.1 PROPOSED BUSINESS MODEL

The proposed model is a Mechanical-Biological Treatment with Waste-to-Energy (MBT+WtE) facilities at MRSP. These facilities would supply the economy with the waste treatment service, recyclables (metal, plastic, glass, and paper), organic compost (bio-fertilizer) and electricity (xxx). The article is not considering the potential revenues from energy generation through anaerobic digestion and steam from the WtE facilities.

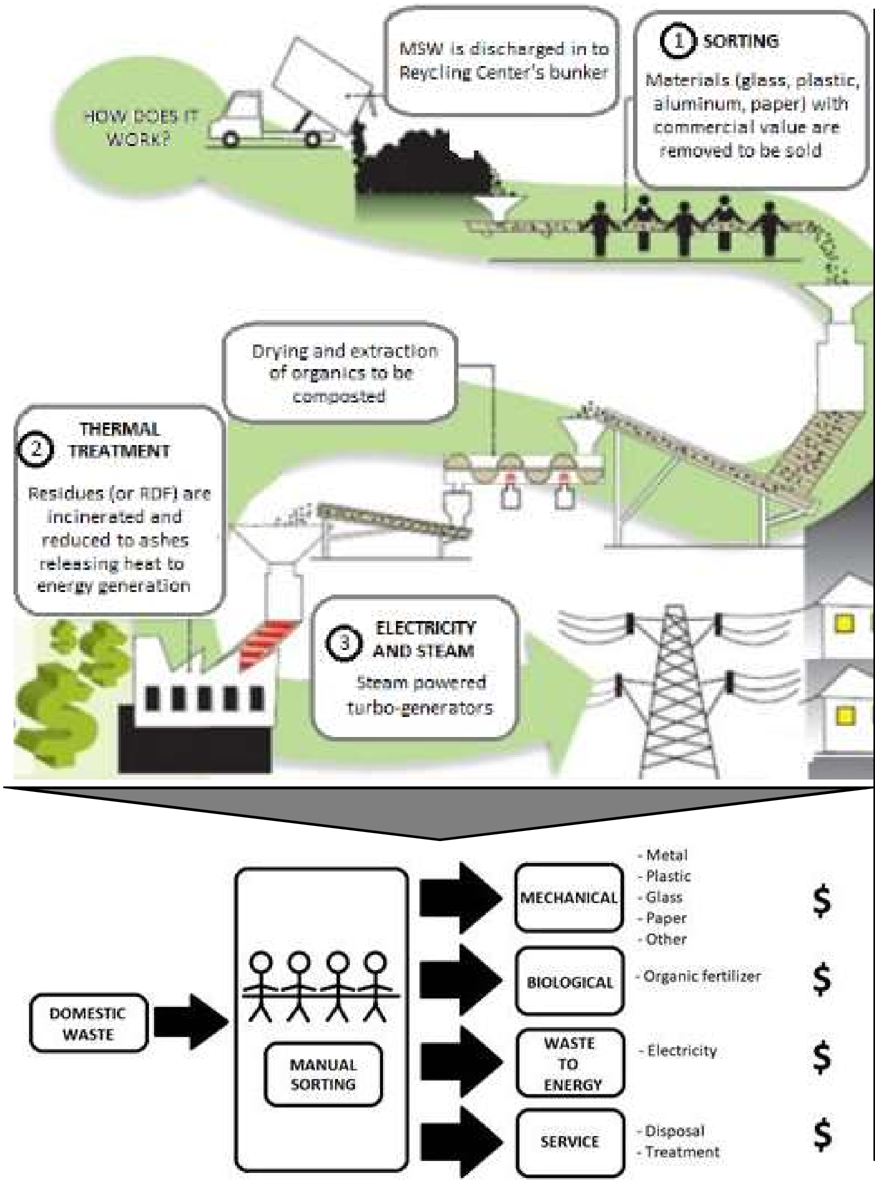

Figure 2.1.1. Integrated waste recovering plant, or MBT+WtE facility

Source: Author´s process flow drawing

IMPORTANT ASSUMPTIONS:

- Sorting phase done by workers formally contracted;
- Sorting phase may be an alternative to cooperatives of recyclables (where not available), or work in partnership with them;
- Operation must consider all requirements of safety and health at work;
- Previous segregation done by society would be better to improve the efficiency and work conditions; and
- Technical capacitation is a must to sort and to operate WtE assets.

The well-succeed practice of MSW treatment with energy generation in too many countries in Europe, especially in Germany, is in the state-of-the-art technology regarding controlled emission and land-use mitigation, as mentioned in last COP 21 (CHRISTENSEN et al., 2015). There, facilities receive materials from the recyclables collection and separate them to reintroduction in the market, reducing demand for more “virgin” materials and energy. Organics are aerated and well-drained to produce fertilizers because biogas through anaerobic digestion in reactors is not viable yet, as explained in Literature Review in section **1.4**.

The remaining waste, or RDF (Refuse-Derived Fuel), burns under high temperatures in closed systems where gases are washed, filtered and submitted to long periods of residence enough to break chemical components. Ashes are the particulate by-products obtained by the incineration. Both ashes and gases must attend legislation requirements described in **Table 2.1.1**.

Table 2.1.1. Standards for Systems of Residues’ Thermal Treatment

RESTRICTIONS	CONAMA 316/2002 (mg/Nm³)	US-EPA (mg/Nm³)	EU-2000/76/EPC (mg/Nm³)
Particulate material	70	11	10
Cl_2	n.d.	n.d.	10
HCl	80	29	10
HF	5	n.d.	1
SO_2	280	63	50
NO_x	560	264	200
CO (ppm)	100	45	50
Heavy Metals Class I (e.g. Cd)	0.28	n.d.	0.05
Heavy Metals Class II (e.g. Hg)	0.28	0.06	0.05
Heavy Metals Class III (e.g. Pb)	6.2	n.d.	n.d.
Dioxins and furans (ng/Nm³)	0.1 - 0.5	0.14	0.1

Source: Compilation from CONAMA (CONAMA, 2002), EPA (US EPA, 2016) and European Standard (EPC, 2000)

Brazil has local legislation that guides residues thermal treatment. The Resolution CONAMA No.316/2002, which defines procedures and criteria for treating them thermally, is too comprehensive as American and European legislation who allow WtE facilities to operate their countries (CONAMA, 2002). As seen in the table above, assumed a technology well-established in any mentioned regions, risks for health and environmental seem to be under control and attending the Brazilian resolution. However, due to security reasons, it should be considered technologies which can meet a more restrictive standard, such as the European one which is more rigorous with emissions and control procedures.

Initially, only depleted mines of minerals (e.g., coal) received ashes to fill them and reduce the environmental impact caused by the mining, but nowadays cement and pavements are receiving them, and other applications are under development (LYNN et al., 2016).

2.1.1 WASTE GRAVIMETRY, PROCESSES, AND PRODUCTS

The gravimetric composition assumed to MRSP's MSW is the one used by Municipal Environmental Sanitation Service of Santo André, a social and economic of Santo André, a representative city from MRSP, described in SEMASA (SEMASA, 2008). Even being a data from 2008, it perfectly aligns with the Brazilian Institute for Applied Economic Research (IPEA) study performed four years later, where MRSP's waste composition is shown (IPEA, 2012).

Table 2.1.1.1 summarizes and brakes-down the weight fractions of waste, the processes where it will be and what products and service will come from the MBT+WtE model.

Table 2.1.1.1. Estimate mass balance

IN		PROCESS		"RAW MATERIALS"		OUT PRODUCTS/SERVICE
MSW	100%	Biological	43%	Organic	43%	Fertilizer
		Mechanical (Recycling)	24%	Paper	8%	Recyclables
				Plastic	8%	
				Metal (i.e. aluminum)	1%	
				Glass	1%	
				Other (e.g., electronics)	6%	
		WtE	33%	Dirty plastics	24%	Electricity
				Cloths, dirty papers, city cleaning	9%	
						Treatment
TOTAL	100%		100%		100%	

Source: Compilation from **Table B 1**, **Table B 2** e **Table B 3**

Fractions of the 21 thousand metric tons per day of waste treated in each process are in **Table B 1** and **Table B 2**. The information about mass amount fractioned in "wet" and "dry" portions are an idea of how much is possible to recover from a simple sorting. Without any additional process (washing and drying), recyclers would buy recyclables (metal, plastic, glass, and paper) compacted and in bales. Organics, the fraction extremely wet in the waste, would be segregated to produce bio-fertilizer. Other waste contents also considered wet, but recognized as dirty (e.g., plastic bags, toilet paper, absorbents, diapers, and general disposables), would be separated to burn due to their high LCV but non-viability to clean and sell them.

Note the expressive waste recovery rate of 67% potentially achieved, considering organic composting and recycling. In a scenario of average waste composition with 61% of organics, MIEZAH estimates 76% of rate recovery in Ghana (MIEZAH et al., 2015). It would be a remarkable level in comparison with the 10% for recyclables sought by São Paulo, and not achieved by now, or with the insignificant 2% performed nowadays in Brazil, by ABRELPE (Brazilian Association of Waste Companies) (ABRELPE, 2014). Besides that, this rate would fit developed European countries, according to the European Environmental Agency's (EEA) data (EEA, 2014).

2.1.2 POTENTIAL REVENUES, ASSETS AND INVESTMENT

To the baseline year 2013, revenues from sales of products and service were calculated assuming market prices (**Table 2.1.2.1**), Lower Calorific Value (LCV) references (**Table B 3**), and the average LCV of the waste in the MRSP (**Table B 4**).

Table 2.1.2.1. Prices and fees for sales revenues in 2013

REVENUE	ORIGIN	2013's MARKET PRICES				REFERENCES
MSW disposal	Service	80	R$ per metric ton	34	USD per metric ton	(ABRELPE, 2016) (CETESB, 2014)
Recyclables	Metal (i.e. aluminum)	2,800		1,197		(CEMPRE, 2013)
	Glass	180		77		
	Paper	510		218		
	Plastic	1,700		726		
	Fertilizer	125		53		
Energy	Electricity	197	R$ per MWh	84	USD per MWh	(ANEEL, 2013)

Source: Author's elaboration based on market references

Mainly talking about WtE facilities, technical configuration no.3 (**Table 2.1.2.2**) and electricity fee were used to calculate their revenues. This assumption is reasonable due to the previous sorting of "wet" and "dry" fractions which improves the LCV to highest levels, as suggested by BOSMANS when discussing benefits of combining Waste-to-Products (WtP) and Waste-to-Energy (WtE) technologies (BOSMANS et al., 2013).

The economic analysis follows considering a WtE technology benchmark which has more than 150 years of experience in more than 15 countries and 2,800 employees. With 160 plants working all over the world and treating 24 million tons per year, this market reference presents a technology with the best relation between investment and RDF's treatment capacity of USD 86 per metric ton in 10 years. Studies from The World Bank's procedures (BANK, 2000) and FEAM, a Brazilian State Environmental Foundation (FEAM, 2012) and NIXXON (NIXXON et al., 2013) ratified this market assumption.

Table 2.1.2.2. Configurations and specs for WtE units

Config.	Waste Capacity (m ton/day)	Min. LCV (kcal/kg)	Installed Capacity (MW)	Operation (h/year)	Electricity Potential (MWh)	Electricity Efficiency
#1	600	1,200	10	8,000	80,000	29%
#2	600	3,200	26	8,000	208,000	28%
#3	600	5,200	42	8,000	336,000	28%
#4	600	6,600	60	8,000	480,000	31%

Source: Market reference's spec and available configurations (CNIM, 2018)

Considering an average exchange of R$ 2.34 per USD in 2013's Brazilian Exchange, the estimated investment to attend MRSP is R$ 4.5 billion (or USD 1.9 billion) (BACEN, 2018). The market recommends units with 600 metric tons per day of capacity (i.e., investment of R$ 450 million, or USD 194 million, per unit) because of technical issues (units availability and maintenance). Due to this, the MRSP should have 12 units well distributed to treat 33% of its waste daily as shown in **Table 2.1.2.3**. São Paulo, the biggest city in MRSP, would be served by 7 MBT+WtE facilities. Other five ones would be covering the rest of the metropolitan region, shown as regions purple, red, yellow, green and blue.

Table 2.1.2.3. Proposed distributions of MBT+WtE facilities at MRSP in 2013

REGION	QTY (m ton/day)	MBT (m ton/day)	WtE (m ton/day)	NR OF UNITS (600 m t)	CAPACITY	ESTIMATED INVESTMENT R$ (USD) billion
Purple	928	622	306	2	86%	0.9 (0.4)
Red	455	305	150			
Yellow	1,762	1,180	581			
Green	2,714	1,819	896	3	100%	1.5 (0.6)
Blue	2,698	1,808	890			
Gray	12,800	8,576	4,224	7	100%	3.4 (1.5)
TOTAL	**21,357**	**14,309**	**7,048**	**12**	**98%**	**5.8 (2.5)**

Source: Compilation from **Figure C 1**

Based on CNIM and past articles considering MBT+WtE facilities, the total investment assumed to have all 12 facilities serving the MRSP in 2013 would be R$ 5.8 billion (or USD 2.5 billion), or 1.3 times of what is required to have only WtE facilities.

This article is not considering an MBT with anaerobic digestion, but only assets to sort recyclables (conveyors and compactors), dryers and blowers to aerobic composting. In the case of anaerobic digestion's MBT assets, factor 1.3 must increase to 4 as remarked by WHEELER, WEKA and EPE reports (EPE; MME, 2018; WEKA, 2013; WHEELER, 2006). Moreover, due to the heterogeneous composition of the organic fraction of the urban waste, there is a pretty low efficiency on gas production when compared with systems fed with sewage sludge, agriculture, and livestock residues as already mentioned in section **1.4**.

2.1.3 FIXED, VARIABLE EXPENSES AND CAPITAL COST

Operational and Maintenance (O&M) costs for MSW's treatment are between USD 50 and 110 per metric ton, based on the previous study, fulfilling rigorous best practices of production and emissions' control (BANK, 2000; FEAM, 2012; NIXXON et al., 2013).

All facilities would use some resources from the economy, such as public (gas, water, urban cleaning) and maintenance services, especially when a WtE asset needs to meet sustainable aspects as discussed by JAMASB (JAMASB and NEPAL, 2010). MBT+WtE facilities usually produce 8% of ashes (relative to the weight amount burnt) as a by-product, and they need to dispose of them. Maintenance and overhauling are also eventually required to keep the facilities working correctly. Therefore, it takes in this study 1.5% and 6% of the annual gross income to by-product disposal and maintenance, respectively, as mentioned by The World Bank and EPE reports (BANK, 2000; EPE; MME, 2008).

Other import operational assumption to the MBT+WtE model is the number of jobs. Following what is recommended by FERRI, when considering collectors to select materials manually, it is strongly recommended to use one collector picking up 730 metric tons of waste per year (FERRI et al., 2014). This parameter sounds reasonable if considered the estimated mass balance in Table 2.1.1.1. Taking into account this assumption, each collector would set-aside 43% of organics (313.9 mt per year) to dry and 33% of dirty materials (240.9 mt per year) to burn. Recyclables would be 8% of paper (58 mt per year), 8% of plastic (58 mt per year), 1% of metal (i.e. aluminum) (7.3 mt per year), 1% of glass (7.3 mt per year) and 6% of other (i.e. electronics) (43.8 mt per year). In comparison with a petrochemical production efficiency of plastics, the operation is more than 34 times smaller. So, this article accounts 10,678 workers, including those (to operate the WtE process. Besides that, the payroll considers two minimum wages per worker including labor costs and benefits, meeting Consolidated Labor Laws (CLT) in Brazil (see **Table D 1**) (BRASIL, 1943).

This formal remuneration represents twice more of what people can get from the casual (or informal) collection in cooperatives at São Paulo city, based on CEMPRE's (Brazilian Association for Business Commitment to Recycling) information (CEMPRE, 2013).

Table 2.1.3.1 presents labor costs, operation expenses, sectorial contributions, taxes and assets accounts followed with local market practices.

The Law No. 9,991/2000 requires 1% of the net operating income (NOI) for electricity generation ventures (DEPUTADOS, 2000). However, this thesis adopted The World Bank's recommendation based on 0.5% of the total investment, or the equivalent to 1.55% of the NOI (BANK, 2000).

The National Agency for Electrical Energy (ANEEL) gives exemption to Distribution (TUSD) and Transmission (TUST) fees since the auction for an alternative source of energy in 2007. Generation plants based on biomass, including MSW, with power capacity between 30 and 50 MW are eligible by the ANEEL's Resolution No. 482/2012 in its Article 3 and paragraphs III and IV (ANEEL, 2012).

Table 2.1.3.1. The breakdown of operational costs

OPERATIONAL EXPENSES · VC – Variable cost · FC – Fixed cost	VALUE DESCRIPTION		UNIT	REFERENCES
WTE's human resource (CF)	% of the investment	3.1	%	(BANK, 2000)
Material consumption (VC)		0.9		
Third party's service (FC)		1.5		
Maintenance (FC)		1.8		
Overhauling (FC)		1.8		
Sorting's human resource (FC)	1 labor per 730 metric ton per year of MSW	46 (20)	R$/metric ton year * (USD/metric ton year)	(FERRI et al., 2014)
OTHER OPERATIONAL	**VALUE DESCRIPTION**			**REFERENCES**
Insurance	0.06% x Investment			(BANK, 2000)
R&D	0.5% x Investment			
TUSD (Distribution fee)	-			(ANEEL, 2007)
TUST (Transmission fee)	-			
TFSEE (sector's service rate)	R$ 470.63 per installed kW			(ANEEL, 2013)
ONS's contribution (sector's rate)	R$ 0.1/MWh			(ANEEL, 2007)
CCEE's contribution (sector's rate)	R$ 0.1/MWh			
Depreciation	10 years			Market practice
IRPJ (income tax)	25% x Profit			(RFB, 2018)
CSSL (social contribution)	9% x Profit			
CAPEX	5% x Investment			(BANK, 2000)

(*) Considering remuneration of two 2014's minimum wage plus CLT's costs and benefits (BRASIL, 2017)
Source: Author's elaboration based on market references

Capital for civil engineering, machines for treating recyclables and organics, filters, particulates and gas washers are in CAPEX provisioned as 0.5% of the investment, as recommended by The World Bank (BANK, 2000).

In the case of funding, the National Bank of Economic and Social Development (BNDES), a Brazilian federal bank has a credit line for Environmental Sanitation and Water Resources. This line has an annual TLP (Brazilian Long-Term Interest Rate), 1% of BNDES's premium and more 1% accounted as risk, covering 80% of the investment done by entrepreneurs (private and public players) (BNDES, 2018).

2.1.4 FINANCIAL ANALYSIS AND LEVEL OF CONFIDENCE FOR RISK

All economic viability was taking into account a cash flow period of 20 years, aligned to the period of municipal concession given to an entrepreneur, and a depreciation of 10 years.

Revenues, Expenses (Fixed and Variable) and Financial costs were broken-down to understand where strengths and weak points of the financial analysis would be for the year 2013.

This study used Monte Carlo Method to measure the risk through the confidence calculated by the simulation using 10,000 random scenarios. Based on almost 20 years' series of input variables (prices for products and service, exchange, investment, amount of waste, and more), these scenarios allowed to calculate other 10,000 decision output variables (NPV, IRR, and PAYBACK). All available records of these variables are in **Table 2.1.4.1** below and assumed as a normal distribution.

Table 2.1.4.1. References to calculate 10,000 scenarios of decision

PARAMETERS	**Min** (x-3σ)	**Max** (x+3σ)	**Mean** (x)	**Std dev** (σ)	References
Investment (R$ billion)	5.3	6.4	5.8	0.2	(CNIM, 2018)
Exchange (R$/USD)	0.82	4.17	2.50	0.56	(BACEN, 2018)
Amount of Waste (k metric ton per day)	15.2	21.4	18.3	1.0	(ABRELPE, 2016)
Destination Fee (R$ per metric ton)	35	120	77	14	
Metal scrap (R$ per metric ton)	1,300	3,300	2,300	333	
Glass scrap (R$ per metric ton)	162	198	180	6	
Paper scrap (R$ per metric ton)	150	510	330	60	
Plastic scrap (R$ per metric ton)	600	2,200	1,400	267	
Organic fertilizer (R$ per metric ton)	100	150	125	8	
Electricity (R$ per MWh)	90	430	260	57	(MME, 2016)
Minimum Wage (R$ per month)	240	954	597	119	(BRASIL, 2017)
Annual Interest rate for funding (%)	6.8	9.5	8.2	0.4	(BNDES, 2018)
Annual TLP (former TJLP) (%)	4.8	7.5	6.2	0.4	(BNDES, 2018)

Source: Author's elaboration based on the market's references from 2000 to 2018

Taking into account historical moments of crises in the USA and Europe, where the technology is well-used, is reasonable to consider an investment range of +/- 10% based on the original budget of R$ 5.8 billion (or USD 2.5 billion) calculated to 2013.

Concerning waste generation rate, based on ABRELPE and CETESB's (Brazilian Environmental Sanitation Technology Company) data, last ten years represented a growth of more than 40% in the amount, or +3,5% per year (ABRELPE, 2014; CETESB, 2014).

All economic viability analysis considered 100% on equity investment. BNDES's rates (TLP + 1% of RISK + 1% Bank's premium) were taking into account as a reference in case of funding hypothesis, and the TLP (Brazilian Long-Term Interest Rate) carried out as the hurdle rate to check the project's economic viability.

2.2 INPUT-OUTPUT MODELING

The model proposed in this article intends to simulate the impact of a new sector responsible for treating MSW in the economy of MRSP. This sector, called here as MBT+WtE, would offer the service of MSW treatment, recyclable materials (metal, plastic, glass, and paper), the organic compost (fertilizer) and energy (electricity) which could replace current "virgin" products (services, materials, and power) in the market.

The economy and its interregional transactions where the I-O model works is the one organized in 62 sectors and their 116 products from 2009's Use and Make tables estimated by GUILHOTO and updated by the author to reproduce the 2013 IBGE's data using the Brazilian Broad Consumer Price Index (IPCA) accumulated for the period 2010 to 2013 (GUILHOTO, 2009; IBGE, 2017).

Service and products are valued in subsection **2.2.1** and taken into account to feed the proposed model. Replacing current service of MSW treatment and "virgin" materials is natural to expect potential savings of energy consumption and GHG emissions. Subsection **2.2.2** shows the 2013's inventories for energy and emissions and, despite sectors' aggregations, their values were fundamental to confirm them or not.

Due to this, the I-O model proposed will show different impacts in current sectors of the MRSP's economy and other regions, such as the rest of São Paulo State and the rest of Brazil.

In I-O modeling it is not necessary to adopt an economy based only on products or industries' technology. Based on this fact, a combined hypothesis will be used in the same model, so that associations can be done based on new products and services replacing regular ones, or a sector impacting other (MILLER and BLAIR, 2009). There are several different methods to mix these technologies, and CUNHA´s proposal was taken by the author to build a model with the number of products bigger than the sectors (CUNHA, 2005). The subsection **2.2.3** shows the proposition of modeling in an academic way where the new sector, or the MBT+WtE sector, is interacting with the economy through its service and products.

2.2.1 WASTE, POTENTIAL VALUE-ADDED AND OPERATIONAL ASSUMPTIONS

In subsection **2.1.1** were summarized and broken-down processes, products, service, and revenues from the MBT+WtE sector used to impact the economy.

Values (or revenues) to impact the economy were calculated assuming 2013's market prices (**Table 2.1.2.1**), Lower Calorific Value (LCV) references (**Table E 1**) and the average waste's LCV for the MRSP (**Table E 2**).

The energy value used is the one from ANEEL Auction A-5 for biomass generation in 2014, and the amount generated by 12 WtE units would be 4.0 TWh (or 353 k toe) in 2013 (ANEEL, 2013).

Emissions of GHG by WtE units followed BELANGER study which considers biogenic emissions (e.g., cellulose for paper) and he recommends using 460 kg of $CO_{2\ eq}$ per metric ton of waste treated (BELANGER et al., 2009).

Thus, considering service and products offered by the MBT+WtE sector, it is estimated at R$ 3,594 million (or USD 1,800 million) annually added to MRSP's economy. Recyclables (plastic, paper, glass, and metal) would be responsible for 46%, electricity 25%, waste treatment service 17% and organic compost 12% (detailed in section 3.1).

The new sector would use some resources from the economy, such as public (gas, water, urban cleaning) and maintenance services. WtE facilities usually produce 8% (relative to the amount burnt) of ashes as a by-product, and disposed of in landfills, abandoned mines or mixed to build pavements. Maintenance and overhauling are also eventually required to keep the facilities working correctly. So, this study takes on 1.5% and 6% of the annual gross income to by-product disposal and maintenance, respectively (BELANGER et al., 2009; CNIM, 2018; FEAM, 2012).

Other import operational assumption to the MBT+WtE is the number of jobs. Following what is recommended by FERRI, when considering collectors to select materials, it is strongly recommended to use one collector picking up 730 metric tons of waste per year (FERRI et al., 2014). So, this article will account 10,678 workers, including those to operate the WtE process.

2.2.2 INVENTORY OF ENERGY CONSUMPTION AND GHG EMISSIONS

Unfortunately, there are not detailed regional sectorized energy and emissions inventories to the Brazilian economy. Responsible agencies for these issues, such as Mines and Energy Ministry (MME) and/or Science, Technology and Innovation Ministry (MCTI), or national publications, such as National Energy Balance (BEN) and/or System of GHG Estimative (SEEG), make available energy and emissions data extremely aggregated what makes rough task to reach how impacted is a specific sector (see **Table 2.2.2.1**).

In this case, where only 18 sectors are available for all Brazilian economy, and the model was prepared to work with 62 sectors interacting in 3 regions, the author has disaggregated the data based on GDP's subsectors and regions. For example, the Textile's sector has three available subsectors in GUILHOTO's Tables (GUILHOTO, 2009). The total 2013's GDP for this sector was R$ 46,311 million (or USD 23,190 million), where 36% represents the subsector *Textile*, 42% for the subsector *Articles and Accessories of Clothing*, and 22% for the subsector *Leather Goods and Footwear*. These contributions allowed the calculations for the energy consumption and emissions subsector's baseline. In the same way, considering the GDP of each subsector was possible to estimate energy consumption and GHG among the regions.

Table 2.2.2.1. Energy consumption and GHG emissions in 2013

SECTORS	Energy Consumption (*) (10^3 toe)	GHG Emissions (*) (10^6 ton CO_2 eq)
Transport	83,153	214
Energy (Oil & Gas)	26,139	37
Energy (Ethanol)		14
Energy (Electricity)		67
Food and Beverages	23,339	27
Pig Iron, Steel, Ferrous Alloys	17,781	39
Paper and Cellulose Pulp	10,575	12
Agriculture	10,662	74
Livestock		912
Chemical	6,986	8
Commercial	8,064	2
Non-ferrous and other Metals	6,936	15
Ceramics	5,069	6
Public Services (Public Cleaning)	3,868	48
Public Services (Other)		1
Cement	5,316	42
Mining and Pelleting	3,247	7
Textile	1,101	1
Other	7,945	22
TOTAL	**220,181**	**1,548**

(*) Residential sector not considered
Source: BEN (BEN, 2014) and SEEG (SEEG, 2014)

This procedure gives an idea with considerable accuracy on getting subsector's energy consumption and GHG emissions baseline to check the effect of the MRSP's new sector in the entire Brazilian economy.

2.2.3 PROPOSED I-O MODEL – A DIDACTIC APPROACH

Suppose an economy with 12 sectors $\mathbf{S_n}$ (n = 12) and 19 products $\mathbf{Q_m}$ (m = 19), described as follows: $\mathbf{S_1}$ – *MBT+WtE*; $\mathbf{S_2}$ – *Extraction of Non-Metallic Minerals*; $\mathbf{S_3}$ – *Other from Extractive Industry*; $\mathbf{S_4}$ – *Chemical Products*; $\mathbf{S_5}$ – *Aluminum's Metallurgy*; $\mathbf{S_6}$ – *Paper and Cardboard*; $\mathbf{S_7}$ – *Glass*; $\mathbf{S_8}$ – *Resins and Elastomers Manufacturers*; $\mathbf{S_9}$ – *Rubber and Plastic*; $\mathbf{S_{10}}$ – *Oil-Based Electricity Generation*; $\mathbf{S_{11}}$ – *Urban Cleaning Service*; and $\mathbf{S_{12}}$ – *Other from Economy*. And take in account their products: $\mathbf{Q_1}$ – *Organic Compost*; $\mathbf{Q_2}$ – *Aluminum Scrap*; $\mathbf{Q_3}$ – *Paper Scrap*; $\mathbf{Q_4}$ – *Glass Scrap*; $\mathbf{Q_5}$ – *Plastic Scrap*; $\mathbf{Q_6}$ – *Electricity*; $\mathbf{Q_7}$ – *MSW Treatment Service*; $\mathbf{Q_8}$ – *Minerals Extraction for Fertilizers and Other Chemicals Products*; $\mathbf{Q_9}$ – *Non-Metallic Minerals*; $\mathbf{Q_{10}}$ – *Non-Ferrous Metallic Minerals*; $\mathbf{Q_{11}}$ – *Inorganic Chemical Products*; $\mathbf{Q_{12}}$ – *Aluminum Metallurgy*; $\mathbf{Q_{13}}$ – *Paper and Cardboard*; $\mathbf{Q_{14}}$ – *Glass and Products*; $\mathbf{Q_{15}}$ – *Resins*; $\mathbf{Q_{16}}$ – *Rubber and Plastic Articles*; $\mathbf{Q_{17}}$ – *Oil-Based Electricity*; $\mathbf{Q_{18}}$ – *Urban Cleaning Service*; and $\mathbf{Q_{19}}$ – *Other Products from Economy*. The model's formulation derives from a system of equations based on Use (U) and Make (V) matrices whose structures are shown in **Figure 2.2.3.1** and **Figure 2.2.3.2** below. Here, MBT+WtE and its products are mentioned but not used.

Use Matrix (U) $T_{initial}$		X_1 MBT+WtE	X_2 Extraction of Non-Metallic Minerals	X_3 Other from Extractive Industry	X_4 Chemical Products	X_5 Metallurgy of Aluminum	X_6 Paper and Cardboard	X_7 Glass	X_8 Resins and Elastomers Production	X_9 Rubber and Plastic	X_{10} Electricity Generation (oil based)	X_{11} Urban Cleaning Service	X_{12} Other from Economy	E Final Demand	Q Value of the Products
Q_1	Organic Compounds				$Z_{1,4}$									E_1	
Q_2	Aluminum scrap					$Z_{2,5}$								E_2	
Q_3	Paper scrap						$Z_{3,6}$							E_3	
Q_4	Glass scrap							$Z_{4,7}$						E_4	
Q_5	Plastic scrap									$Z_{5,9}$				E_5	
Q_6	Electricity		$Z_{6,2}$	...	...	...	...	...	...	...	...	...	$Z_{6,12}$	E_6	
Q_7	Service of MSW Treatment		$Z_{7,2}$	...	...	...	...	...	...	...	...	...	$Z_{17,2}$	E_7	
Q_8	Extration of Minerals for Fertilizers and Other Chemical Products				**27.76**									10.00	**37.76**
Q_9	Non-Metallic Minerals				6.94			**11.05**					27.00	20.00	**64.99**
Q_{10}	Non-Ferrous Metallic Minerals				2.78	**12.06**							40.50	25.00	**80.34**
Q_{11}	Inorganic Chemical Products		11.29	7.48	8.33	0.80	8.06	5.16	4.07	0.86	0.26	0.04	54.00	15.00	**115.34**
Q_{12}	Aluminum's Metallurgy					3.22							27.00	10.00	**40.60**
Q_{13}	Paper and Cardboard			2.14	1.39	1.21	**25.20**	0.74	0.68	0.86	0.13	0.04	40.50	30.00	**102.87**
Q_{14}	Glass and its Products				1.39		1.01	3.68					27.00	40.00	**74.44**
Q_{15}	Resins									**29.98**			13.50	25.00	**68.48**
Q_{16}	Rubber and Plastics parts		5.65	2.14	5.55	4.02	3.02	1.47	1.36	2.57	0.38	0.14	27.00	35.00	**88.30**
Q_{17}	Electricity (oil based)		**0.21**	**0.54**	**0.41**	**0.18**	**0.44**	**0.44**	**0.21**	**0.10**	**0.01**	**0.03**	**0.20**	**10.00**	**12.78**
Q_{18}	Urban Cleaning Service		**0.12**	**0.07**	**0.13**	**0.01**	**0.16**	**0.04**	**0.02**		**0.01**		**1.20**	**2.00**	**3.77**
Q_{19}	Other Products from Economy		28.24	34.17	55.52	8.04	24.19	15.48	28.47	14.56	4.98	1.20	688.52	500.00	**1,403.38**
X^T	**Production Value**		**112.95**	**106.80**	**138.80**	**40.19**	**100.81**	**73.69**	**67.79**	**85.66**	**12.78**	**3.54**	**1,350.04**	(monetary units)	

Figure 2.2.3.1. Original Use matrix (U) based on the type of industries and products (combined technology)

The matrix (U) shows sectors and products used in their productions. Moreover, matrix (V) presents products used in the production of each sector.

Make Matrix (V)		Q_1 Organic Compounds	Q_2 Aluminum scrap	Q_3 Paper scrap	Q_4 Glass scrap	Q_5 Plastic scrap	Q_6 Electricity	Q_7 Service of MSW Treatment	Q_8 Extration of Minerals for Fertilizers and Other Chemical Products	Q_9 Non-Metallic Minerals	Q_{10} Non-Ferrous Metallic Minerals	Q_{11} Inorganic Chemical Products	Q_{12} Aluminum's Metallurgy	Q_{13} Paper and Cardboard	Q_{14} Glass and its Products	Q_{15} Resins	Q_{16} Rubber and Plastics parts	Q_{17} Electricity (oil based)	Q_{18} Urban Cleaning Service	Q_{19} Other Products from Economy
X_1	**MBT+WtE**	0.10	0.30	0.10	0.05	0.20	0.20	0.05												
X_2	Extraction of Non-Metallic Minerals								0.9500	0.9700										0.0100
X_3	Other from Extractive Industry										0.9800									0.0200
X_4	Chemical Products											0.9600								0.0200
X_5	Metallurgy of Aluminum												0.9900							
X_6	Paper and Cardboard													0.9800						
X_7	Glass														0.9900					
X_8	Resins and Elastomers Production															0.9900				
X_9	Rubber and Plastic																0.9700			
X_{10}	Electricity Generation (oil based)																	1.0000		
X_{11}	Urban Cleaning Service																		0.9400	
X_{12}	Other from Economy								0.0500	0.0300	0.0200	0.0400	0.0100	0.0200	0.0100	0.0100	0.0300		0.0600	0.9500

Figure 2.2.3.2. Make matrix (V) based on the type of industries and products (combined technology)

The linear system of equations related to the academic model would be as follows:

I. Equation from Make Matrix (V) based on Products considering the new MBT+WtE sector (E. 1)**:**

$$Q = C^{T} \cdot X_1 \qquad \textbf{(E. 1)}$$

$$[Q] = \begin{bmatrix} 0{,}10 \\ 0{,}30 \\ \dots \\ 0{,}05 \end{bmatrix} \cdot X_1 \;\Rightarrow\; \begin{bmatrix} Q_1 \\ Q_2 \\ \dots \\ Q_7 \end{bmatrix} = \begin{bmatrix} 0{,}10 \\ 0{,}30 \\ \dots \\ 0{,}05 \end{bmatrix} \cdot X_1$$

$\text{E.}1-1)\ Q_1 = 0{,}10 \cdot X_1 \Rightarrow 0{,}10 \cdot X_1 - Q_1 = 0$

$\text{E.}1-2)\ Q_2 = 0{,}30 \cdot X_1 \Rightarrow 0{,}30 \cdot X_1 - Q_2 = 0$

$\vdots$

$\text{E.}1-7)\ Q_7 = 0{,}05 \cdot X_1 \Rightarrow 0{,}05 \cdot X_1 - Q_7 = 0$

Where:

X_1 – Production value from sector 1 (MBT+WtE)

C^T – Direct production requirements' coefficient in a sector

Q – Values of 7 seven products from MBT+WtE sector

Based on the economy from **Figure 2.2.3.2** and its direct requirements, it would be necessary seven equations (E. 1).

II. Equation from Make Matrix (V) considering existing sectors in the economy and based on their types of industries (E. 2)**:**

$$X = D \cdot Q \qquad \textbf{(E. 2)}$$

$$\begin{bmatrix} X_2 \\ X_3 \\ \dots \\ X_{12} \end{bmatrix} = D \cdot \begin{bmatrix} Q_8 \\ Q_9 \\ \dots \\ Q_{19} \end{bmatrix}$$

$\text{E.}2-8)\ X_2 = 0{,}95 \cdot Q_8 + \cdots + 0{,}01 \cdot Q_{19}$

$\vdots$

$\text{E.}2-18)\ X_{12} = 0{,}05 \cdot Q_8 + \dots + 0{,}95 \cdot Q_{19}$

Where:

X_n – Production value from 11 sectors of the economy

D – Production technical coefficients from a product in several sectors

Q – Values from 12 products in 11 sectors of the economy

Based on the economy from **Figure 2.2.3.3** with its technical production coefficients, it would be necessary for here eleven equations (E. 1).

III. Equations for the destiny of the MBT+WtE's products in Use Matrix (U) (E. 3):

$$Z + E = Q \qquad \textbf{(E. 3)}$$

$$E.3 - 9)\ Z_1 + E_1 = Q_1$$
$$E.3 - 20)\ Z_2 + E_2 = Q_2$$
$$\vdots$$
$$E.3 - 23)\ Z_5 + E_5 = Q_5$$
$$E.3 - 24) \dots 33) \left(\sum_{j=2}^{12} Z_{6,j}\right) + E_6 = Q_6$$
$$E.3 - 34) \dots 43) \left(\sum_{j=2}^{12} Z_{7,j}\right) + E_7 = Q_7$$

Based on the economy from **Figure 2.2.3.3** below, seven equations (E. 3) would represent MBT+WtE's products destination in the economy.

Use Matrix (U) T_{final}		X_1 MBT+WtE	X_2 Extraction of Non-Metallic Minerals	X_3 Other from Extractive Industry	X_4 Chemical Products	X_5 Metallurgy of Aluminum	X_6 Paper and Cardboard	X_7 Glass	X_8 Resins and Elastomers Production	X_9 Rubber and Plastic	X_{10} Electricity Generation (oil based)	X_{11} Urban Cleaning Service	X_{12} Other from Economy	E Final Demand
Q_1	Organic Compounds				$Z_{1,4}$									E_1
Q_2	Aluminum scrap					$Z_{2,5}$								E_2
Q_3	Paper scrap						$Z_{3,6}$							E_3
Q_4	Glass scrap							$Z_{4,7}$						E_4
Q_5	Plastic scrap									$Z_{5,9}$				E_5
Q_6	Electricity		$Z_{6,2}$	...	...	...	...	...	...	...	...	...	$Z_{6,12}$	E_6
Q_7	Service of MSW Treatment		$Z_{7,2}$	...	...	...	...	...	...	...	...	...	$Z_{7,2}$	E_7
Q_8	Extration of Minerals for Fertilizers and Other Chemical Products				$U_{1,4}$									E_8
Q_9	Non-Metallic Minerals							$U_{4,7}$						E_9
Q_{10}	Non-Ferrous Metallic Minerals					$U_{2,5}$								E_{10}
Q_{11}	Inorganic Chemical Products													E_{11}
Q_{12}	Aluminum's Metallurgy													E_{12}
Q_{13}	Paper and Cardboard						$U_{3,6}$							E_{13}
Q_{14}	Glass and its Products													E_{14}
Q_{15}	Resins									$U_{5,9}$				E_{15}
Q_{16}	Rubber and Plastics parts													E_{16}
Q_{17}	Electricity (oil based)		$U_{6,2}$	...	...	...	...	...	...	...	...	...	$U_{6,12}$	E_{17}
Q_{18}	Urban Cleaning Service		$U_{7,2}$	...	...	...	...	...	...	...	...	...	$U_{7,12}$	E_{18}
Q_{19}	Other Products from Economy													E_{19}

(monetary units)

Figure 2.2.3.3. Proposed Use Matrix (U) considering the new MBT+WtE sector

IV. Equations which represent the destiny of the existing products in the economy and shown in the Use Matrix (U):

$$(B \cdot X) + E = Q \qquad \textbf{(E. 4)}$$

$$E.4 - 44)\ (0{,}00 \cdot X_2 + 0{,}00 \cdot X_3 + \cdots + 0{,}00 \cdot X_{11} + 0{,}00 \cdot X_{12}) + E_8 = Q_8$$
$$E.4 - 45)\ (0{,}00 \cdot X_2 + 0{,}00 \cdot X_3 + \cdots + 0{,}00 \cdot X_{11} + 0{,}02 \cdot X_{12}) + E_9 = Q_9$$
$$\vdots$$
$$E.4 - 46)\ (0{,}25 \cdot X_2 + 0{,}32 \cdot X_3 + \cdots + 0{,}34 \cdot X_{11} + 0{,}51 \cdot X_{12}) + E_{19} = Q_{19}$$

Where:

B – Use technical coefficient from a product in a sector

X – Production value of the sector

B · X – Part of the products from the economy destined to the intermediary consumption

E – Part of the products from the economy destined to the final demand

Q – Products' value from the economy

This topic would have twelve equations (E. 4) based on the economy from **Figure 2.2.3.4** with its technical coefficients.

Technical Coefficients Matrix (B) $T_{initial}$		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	E
		MBT+WtE	Extraction of Non-Metallic Minerals	Other from Extractive Industry	Chemical Products	Metallurgy of Aluminum	Paper and Cardboard	Glass	Resins and Elastomers Production	Rubber and Plastic	Electricity Generation (oil based)	Urban Cleaning Service	Other from Economy	Final Demand
Q_1	Organic Compounds				$Z_{1,4}$									E_1
Q_2	Aluminum scrap					$Z_{2,5}$								E_2
Q_3	Paper scrap						$Z_{3,6}$							E_3
Q_4	Glass scrap							$Z_{4,7}$						E_4
Q_5	Plastic scrap									$Z_{5,9}$				E_5
Q_6	Electricity		$Z_{6,2}$	...	...	...	...	...	...	...	...	...	$Z_{6,12}$	E_6
Q_7	Service of MSW Treatment		$Z_{7,2}$	...	...	...	...	...	...	...	...	...	$Z_{17,2}$	E_7
Q_8	Extration of Minerals for Fertilizers and Other Chemical Products				**0.200**									10
Q_9	Non-Metallic Minerals				0.050			**0.150**					0.020	20
Q_{10}	Non-Ferrous Metallic Minerals				0.020	**0.300**							0.030	25
Q_{11}	Inorganic Chemical Products		0.100	0.070	0.060	0.020	0.080	0.070	0.060	0.010	0.020	0.010	0.040	15
Q_{12}	Aluminum's Metallurgy					0.080					0.030		0.020	10
Q_{13}	Paper and Cardboard			0.020	0.010	0.030	**0.250**	0.010	0.010	0.010	0.010	0.010	0.030	30
Q_{14}	Glass and its Products				0.010		0.010	0.050	0.020				0.020	40
Q_{15}	Resins									**0.350**			0.010	25
Q_{16}	Rubber and Plastics parts		0.050	0.020	0.040	0.100	0.030	0.020	0.020	0.030	0.030	0.040	0.020	35
Q_{17}	Electricity (oil based)		**0.002**	**0.005**	**0.003**	**0.005**	**0.004**	**0.006**	**0.003**	**0.001**	**0.001**	**0.009**	**0.000**	10
Q_{18}	Urban Cleaning Service		**0.001**	**0.001**	**0.001**	**0.000**	**0.002**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	2
Q_{19}	Other Products from Economy		0.250	0.320	0.400	0.200	0.240	0.210	0.420	0.170	0.390	0.340	0.510	500

Figure 2.2.3.4. Original Technical Coefficients' Matrix (B) from the economy

V. Equations for replacing "virgin" products with the ones produced by MBT+WtE sector:

$$Z + U = B \cdot X \qquad \textbf{(E. 5)}$$

$E.5 - 47)\ Z_{1,4} + U_{1,4} = 0{,}200 \cdot X_4$

⋮

$E.5 - 50)\ Z_{4,7} + U_{4,7} = 0{,}150 \cdot X_7$

$E.5 - 51)\ Z_{5,9} + U_{5,9} = 0{,}350 \cdot X_9$

$E.5 - 52)\ Z_{6,2} + U_{6,2} = 0{,}002 \cdot X_2$

⋮

$E.5 - 62)\ Z_{6,12} + U_{6,12} = 0{,}000.X_{12}$

$E.5 - 63)\ Z_{7,2} + U_{7,2} = 0{,}001 \cdot X_2$

$E.5 - 64)\ Z_{7,12} + U_{7,12} = 0{,}001 \cdot X_{12}$

Where:

Z – Recyclable's product value produced by MBT+WtE sector

U – Value of the "virgin" product, which will be replaced by MBT+WtE's products.

As an example, it is shown the value of the product plastic scrap ($Z_{5,9}$) replacing resins value ($U_{5,9}$), attending the product's tech coefficient (B) in the sector Rubber and Plastic (X_9):

$$X_9 = \left(\frac{U_{5,9} + Z_{5,9}}{0{,}350}\right) \qquad \textbf{(E. 6)}$$

Here it is necessary to consider a Techno-Economic Factor (r) to replace "virgin" for recyclable because there are relevant market restrictions to recyclables usage. Thus, the equation (E. 6) to be considered in the model is:

$$X = \left[\frac{U + \left(\frac{Z}{r}\right)}{B}\right] \qquad \textbf{(E. 7)}$$

On a hypothetical case with a Product (P) blended with 60% of recyclable costing (y) 50 less than a "virgin" one, equation (E. 7) is:

$$r_P = \left[\frac{0{,}60 \cdot \left(\frac{y}{2}\right)}{0{,}40 \cdot y}\right] = \left(\frac{0{,}30}{0{,}40}\right) = 0{,}75 \qquad \textbf{(E. 8)}$$

This rational (E. 8) represents 1.0 monetary unit of "virgin" replaced for 0.75 monetary unit of recyclable.

The number of equations here is 27, taking into account the information in **Figure 2.2.3.3** and **Figure 2.2.3.4**.

VI. Equations from Final Demands (E) for the recyclable and "virgin" products to the Families and Government, such as Electricity and Urban Cleaning Service:

$$\mathrm{E.9-65)}\ E_6 + E_{17} = E_{17}^0 \qquad \textbf{(E. 9)}$$

$$\mathrm{E.9-66)}\ E_7 + E_{18} = E_{18}^0 \qquad \textbf{(E. 10)}$$

Where:

E_6 – Final demand for the product Electricity produced by the MBT+WtE sector

E_7 – Final demand for the product Urban Cleaning Service offered by the MBT+WtE sector

E_{17}^0– Initial demand for the product Electricity based on fuel oil in the economy

E_{18}^0– Initial demand for the product Urban Cleaning Service in the economy

E_{17}– Final demand for the Electricity considering the MBT+WtE supply

E_{18}– Final demand for the Urban Cleaning considering the MBT+WtE supply

In this opportunity will not be considered the Techno-Economic Factor (r) because there's no restriction to use the electricity or the cleaning service supplied by the MBT+WtE sector.

Here are only two equations (E. 9) and (E. 10) based on data from **Figure 2.2.3.4**.

VII. Equations to get the new amount of "virgin" when the MBT+WtE sector begins to work in the economy:

$$E_i = \alpha_{i,j} \cdot E_i^0 \qquad \textbf{(E. 11)}$$

$\mathrm{E.}11 - 67)\ E_{17} = \alpha_{17,E_{17}} \cdot E_{17}^0 = 10 \cdot E_{17}^0$
$\mathrm{E.}11 - 68)\ E_{18} = \alpha_{18,E_{18}} \cdot E_{18}^0 = 2 \cdot E_{18}^0$

$$U_{i,j} = \alpha_{i,j} \cdot U_{i,j}^0 \qquad \textbf{(E. 12)}$$

$\mathrm{E.}12 - 69)\ U_{6,2} = \alpha_{6,2} \cdot U_{6,2}^0$
$\vdots$
$\mathrm{E.}12 - 79)\ U_{6,12} = \alpha_{6,12} \cdot U_{6,12}^0$
$\mathrm{E.}12 - 80)\ U_{7,2} = \alpha_{7,2} \cdot U_{7,2}^0$
$\vdots$
$\mathrm{E.}12 - 90)\ U_{7,12} = \alpha_{7,12} \cdot U_{7,12}^0$

Where:

$\mathbf{E_i}$ – New final demand considering the "virgin" products i

$\mathbf{E_i^0}$– Initial demand for the "virgin" products i

$\mathbf{U_{i,j}}$– New use to the "virgin" product i for the sector j

$\mathbf{U_{i,j}^0}$– Initial use to "virgin" product i for the sector j

$\boldsymbol{\alpha_{i,j}}$– Adjustment factor to get the new amount of "virgin" products i, Electricity based on fuel oil and Urban Cleaning Service, for the sectors j

The total equations would be 24, based on data in **Figure 2.2.3.4**.

With all 90 equations and 108 variables in this educational model, it is possible to get ENDOGENOUS (M) and EXOGENOUS (N) matrixes in an equilibrium market hypothesis:

$$M + N = 0 \qquad \textbf{(E. 13)}$$

Where:

M – Values of Supply

N – Values of Demand

The ENDOGENOUS matrix (M) is below, and it is considering only intermediary consumption data:

M

	X_2	…	X_{12}	Q_1	…	Q_{19}	E_6	E_7	E_{17}	E_{18}	Z_1	…	Z_5	$Z_{6,2}$	…	$Z_{6,12}$	$Z_{7,2}$	…	$Z_{7,12}$	$U_{1,4}$	…	$U_{5,9}$	$U_{6,2}$	…	$U_{6,12}$	$U_{7,2}$	…	$U_{7,12}$	$\alpha_{17,j}$	$\alpha_{18,j}$
Eq.1	0,000	…	0,000	-1,000	…	0,000	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮
Eq.7	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
Eq.8	-1,000	…	0,000	0,000	…	0,010	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮
Eq.18	0,000	…	-1,000	0,000	…	0,950	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
Eq.19	0,000	…	0,000	-1,000	…	0,000	0,000	0,000	0,000	0,000	1,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮
Eq.25	0,000	…	0,000	0,000	…	0,000	0,000	1,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	1,000	…	1,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
Eq.26	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	1,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮
Eq.37	0,250	…	0,510	0,000	…	-1,000	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
Eq.38	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000	0,000	1,000	…	0,000	0,000	…	0,000	0,000	…	0,000	1,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮
Eq.64	0,000	…	-0,001	0,000	…	0,000	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	1,000	0,000	…	0,000	0,000	…	0,000	0,000	…	1,000	0,000	0,000
Eq.65	0,000	…	0,000	0,000	…	0,000	1,000	0,000	1,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
Eq.66	0,000	…	0,000	0,000	…	0,000	0,000	1,000	0,000	1,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000
Eq.67	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	-1,000	…	0,000	0,000	…	0,000	0,208	0,000
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮
Eq.90	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000	-1,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	…	0,000	0,000	2,000

90 X 90

To get the impact of introducing the MBT+WtE sector in the SUPPLY (M), it is a must to separate demand’s variables (or EXOGENOUS), including those from the new sector and its production value, as follows:

Exogenous Variables

$$\begin{bmatrix} X_1 \\ E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_8 \\ \vdots \\ E_{16} \\ E_{19} \\ E_{17}^{0} \\ E_{18}^{0} \end{bmatrix}$$

18 X 1

Moreover, this would be the matrix where the SHOCK value (Y) affects the DEMAND (N):

-N

	X_1	E_1	…	E_5	E_8	…	E_{16}	E_{19}	E_{17}^{0}	E_{18}^{0}
Eq.1	-0,100	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
Eq.7	-0,050	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
Eq.8	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
Eq.18	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
Eq.19	0,000	-1,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
Eq.25	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
Eq.26	0,000	0,000	…	0,000	-1,000	…	0,000	0,000	0,000	0,000
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
Eq.37	-0,300	0,000	…	0,000	0,000	…	0,000	-1,000	0,000	0,000
Eq.38	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
Eq.64	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
Eq.65	0,000	0,000	…	0,000	0,000	…	0,000	0,000	1,000	0,000
Eq.66	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	1,000
Eq.67	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
Eq.90	0,000	0,000	…	0,000	0,000	…	0,000	0,000	0,000	0,000

90 X 18

Multiplying the matrices $[-\text{N}]_{90\,\text{X}\,18} \cdot [\text{EXOGENOUS VARIABLES}]_{18\,\text{X}\,1}$ the SHOCK value is obtained to be done on the economy's intermediary consumption, as follows:

$$[\text{M}]^{-1}_{90\,\text{X}\,90} \cdot [\text{SHOCK}]_{90\,\text{X}\,1} = [\text{IMPACT}]_{90\,\text{X}\,1} \qquad \textbf{(E. 14)}$$

This IMPACT is noted on the ENDOGENOUS VARIABLES, or on the new composition of products from the MBT+WtE sector and the existing ones in the economy:

$$\textbf{Endogenous Variables} \begin{bmatrix} X_2 \\ \vdots \\ X_{12} \\ Q_1 \\ \vdots \\ Q_{19} \\ E_6 \\ E_7 \\ E_{17} \\ E_{18} \\ Z_1 \\ \vdots \\ Z_5 \\ Z_{6,2} \\ \vdots \\ Z_{6,12} \\ Z_{7,2} \\ \vdots \\ Z_{7,12} \end{bmatrix}_{90\ X\ 1}$$

The introduction of this new sector in the economy brings new alternative products and services, including jobs, which could socially and economically impact the regional and national economy through the amount of MSW generated.

Once impacted, it is possible to analyze the economy with the new sector through Direct and Indirect effects on Production values (X), as shown below:

$$X = X_{direct} + X_{indirect} \qquad \textbf{(E. 15)}$$

The Production value affected by the direct effects (X_{direct}) is the result of the SHOCK (Y) and the direct inputs from several economy's sectors (n):

$$X_{direct} = Y + \sum_{1}^{n} A^n \cdot Y \qquad \textbf{(E. 16)}$$

Alternatively,

$$X_{direct} = (I + A) \cdot Y \quad \textbf{(E. 17)}$$

Remembering that:

$$X = (I - A)^{-1} \cdot Y \quad \textbf{(E. 18)}$$

Then:

$$X_{indirect} = X - X_{direct} \quad \textbf{(E. 19)}$$

If considering the Value of the Products (Q), with the equation (E. 4) in (E. 2), it has:

$$B \cdot D \cdot Q + E = Q$$
$$E = Q - B \cdot D \cdot Q$$
$$E = (I - B \cdot D) \cdot Q$$

$$Q = (I - B \cdot D)^{-1} \cdot E \quad \textbf{(E. 20)}$$

Thus, with the equation (E. 17), the value of products under direct effect (Q_{direct}), is given by:

$$Q_{direct} = (I + B \cdot D) \cdot E \quad \textbf{(E. 21)}$$

As in (E. 19):

$$Q_{indirect} = Q - Q_{direct} \quad \textbf{(E. 22)}$$

2.2.4 TECHNICAL AND ECONOMIC FACTS ABOUT USING RECYCLABLES

The use of recyclables replacing "virgin" raw materials offers some advantages, mainly when saving resources, such as:

- *Energy*
- *Water*
- *Minerals*
- *Fuels*
- *Others*

Once part of the value chain would have less production, it is expected a sensitive GHG emission reduction, detailed in subsection 2.2.2.

However, it must be considered technical and economic aspects when replacing “virgins” with recyclables.

Concerning technical aspects, it is important to emphasize the negative impacts of reprocessing and contamination, which can compromise recyclables use. A classic example is that one for plastic materials. In the process of transformation into products, the thermal and mechanical cycle can break primary chemical bonds, which results in reducing some mechanical properties, such as tensile strength. Once the product reaches the end of its life, and after its discard to be reprocessed, it is foolhardy its use in the same application. In Brazil, the National Health Surveillance Agency (ANVISA) prohibits to use recyclable plastics to produce packaging and devices that will be in contact with food. However, excepting other applications such as automotive, plastic bags, containers and other domestic appliances can have from 20% to 100% of recyclables in their composition (ANVISA, 2016). In bags used to carry waste is common to be produced using 100% recyclable plastic with improved mechanical resistance and some losses of visual aspect increasing their thickness and using some pigments, dyes or whitening.

From an economic point of view, it is common to find a range of prices for recyclable plastics, which goes from 20 to 80% of the “virgin” product.

So, taking as a basis the example where, technically, in average is found in blends with 60% of recyclable plastics, the total cost for the raw material is:

$$\text{Total Cost (raw material)} = 0.60 \cdot \text{Price for recyclable} + 0.40 \cdot \text{Price for "virgin"}$$

Considering the economic factor where, on average, the recyclable costs 50% less than the “virgin”, the cost is:

$$\text{Total Cost (raw material)} = 0.60 \cdot (0.50 \cdot \text{Price for "virgin"}) + 0.40 \cdot \text{Price for virgin}$$

Calculating the Techno-Economic Factor (r) to replace “virgin” for recyclable:

$$r_{\text{Plastic}} = \frac{0.60 \cdot (0.50 \cdot \text{Price for "virgin"})}{0.40 \cdot \text{Price for "virgin"}} = \frac{0.30}{0.40} = 0.75$$

Other recycled materials, such as paper and organic, also follow the same rationale that considers technical and economic factors. However, there are instances where there is no technical restriction of product replacement, for example, is the case of aluminum scrap. Thus, it takes on 100% recycled can replace "Virgin" aluminum only the price would be different between them. By ABAL (Brazilian Aluminum Association) and CEMPRE (Business Commitment for Recycling) in 2013, the average price of scrap aluminum was 2,800 R$/t, while the aluminum "Virgin" on average was R$ 3,279/t. Thus, the calculation of r factor of aluminum replacement will be (1) (2):

$$r_{\text{Aluminum}} = \frac{\text{Price for recyclable}}{\text{Price for "virgin"}} = \frac{\text{R\$ 2,800/t}}{\text{R\$ 3,279/t}} = 0.85$$

Besides aluminum, recycled glass, as well as electricity and MSW treatment service, offered by the large-scale integrated model in this article, also follow considering in their r factor the price ratio because there is no technical restriction to replace. **Table E 3** presents the technical-economic factors (r) mentioned in subsection 2.2.4 and used in the results discussed in **CHAPTER 3**.

Thus, the r factor must be read, for example in the use of plastic, as each one monetary value expended to the "Virgin" plastic would replace by 0.75 monetary value of recyclable.

2.3 KICKING OFF A CHALLENGE TO THE CURRENT NATIONAL POLICY FOR SOLID WASTE

This article brings a status' update from all challenges established by the PNRS, and all information extracted from recognized Brazilian offices, associations and institutes which manage sanitation' data, especially those who are specialized on waste and recycling.

Once clearly shown evolution and current situation, the author intends to approach with tire's recycling initiative in Brazil which places goals to achieve its challenges. Improving the Brazilian policy and help it to reach its goals, the suggestion is to define some targets to materials, such as paper, plastic, and glass and charge them from their producers, as suggested by ROGOFF (ROGOFF and ROSS, 2016). The policy, as it is originally, requires only a global level of 20% and let to the municipalities to define their strategies and this empowerment is not working.

Here the idea is to propose a technique based on the fraction of materials available in the market to calculate a minimum recycling rate to be reached globally, per material and tracking who and from where would be the producer (petrochemical, paper, and cellulose, glass, imported or local one).

Taking this parameter as the apparent consumption which is possible to recycle and measuring the market sources, it is possible to discover the minimum recycling rate for each material. Similar to what happens in tires' case that uses a wear fraction of 30% for replacement, the following equation (E. 23) could be:

$$\mathrm{AR} = \mathrm{AC} \times \mathrm{DF} \qquad \textbf{(E. 23)}$$

Where:

AR – Amount to be Recycled

AC – Apparent Consumption

DF – Disposable Fraction (or fraction of all plastic produced for disposables' applications)

To track possible sources of materials and later attribute their goals, equation (E. 24) as follows:

$$\mathrm{AC} = (\mathrm{LP} + \mathrm{I}) - \mathrm{E} \qquad \textbf{(E. 24)}$$

Where:

LP – Local Production

I – Imports

E – Exports

Moreover, finally, equation (E. 25) through (E. 24) in (E. 23) to calculate the recyclable amount:

$$\mathrm{AR} = [(\mathrm{LP} + \mathrm{I}) - \mathrm{E}] \times \mathrm{DF} \qquad \textbf{(E. 25)}$$

Economy effects, such as a crisis or sudden growth which can impact consumption and its demand profile for durable or disposable applications, will be mitigated in this article presenting results through the average of the last four years of data availability.

CHAPTER 3. RESULTS AND DISCUSSIONS

3.1 ECONOMIC VIABILITY ANALYSIS

Considering potential revenues through the MBT+WtE model to the year 2013, 58% of them would be from sales of recoverable materials (metal, plastic, paper, glass, and bio-fertilizer). Electricity would represent 25% and 17% coming from the service of MSW treatment provided to the cities at MRSP (see **Figure 3.1.1**).

Plastic and bio-fertilizer would represent 48% and 20% of the total amount of recoverable' revenues.

Attending the entire MRSP with 12 units, the model considers 504 MW of installed capacity and would generate 4.5 TWh of electricity in 2013. This amount of energy would be equivalent to 25% of the thermoelectric supply for the State of São Paulo, or 2% for the Brazilian territory. All public lighting demand in the State of São Paulo would have the electricity produced and sold by MBT+WtE facilities at MRSP (SEMESP, 2014).

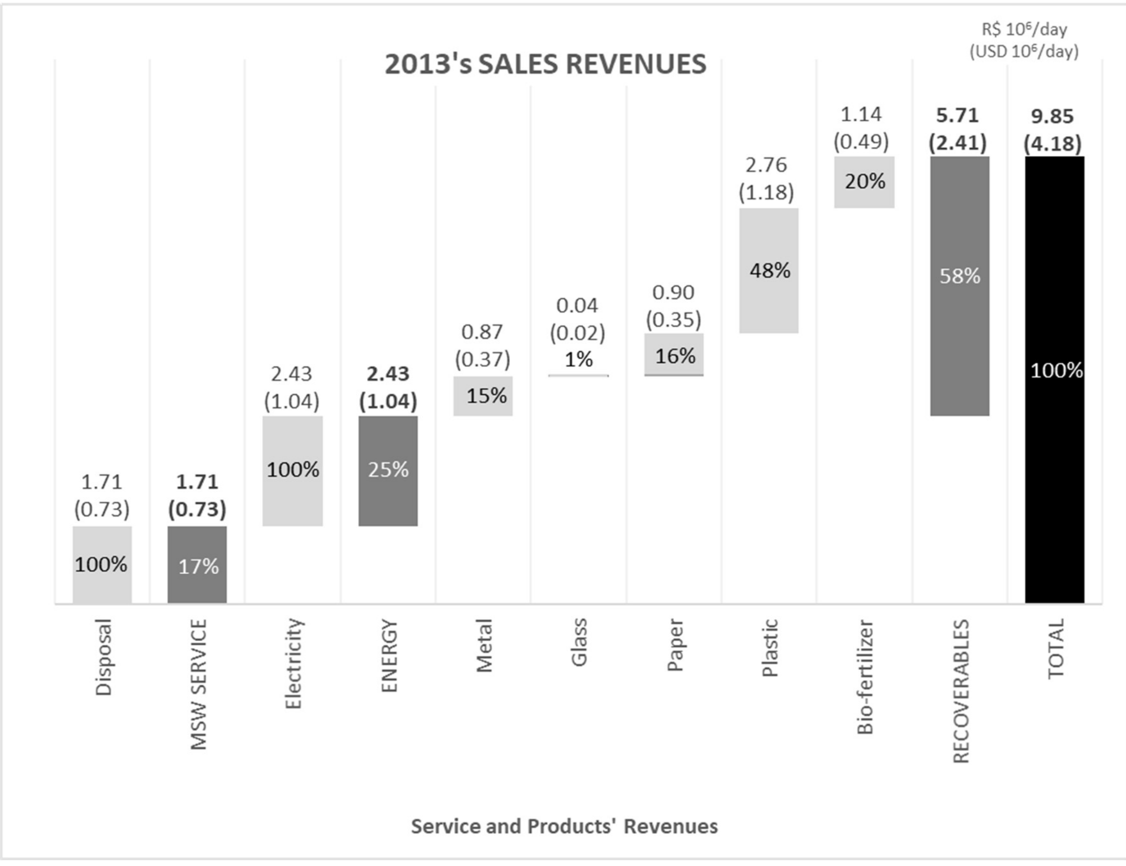

Figure 3.1.1. Potential sales revenues

The waste recycling rate would rise from the current 4% to up 24% or considering organic compost; the waste recovery rate could reach 67%.

Assumptions of operational and financial costs in the model would consume 56% of gross revenue, resulting in a pocket margin of 44% (see **Figure 3.1.2**). In absolute value, this margin would be, in 2013, 26% of the total budget invested in the MRSP.

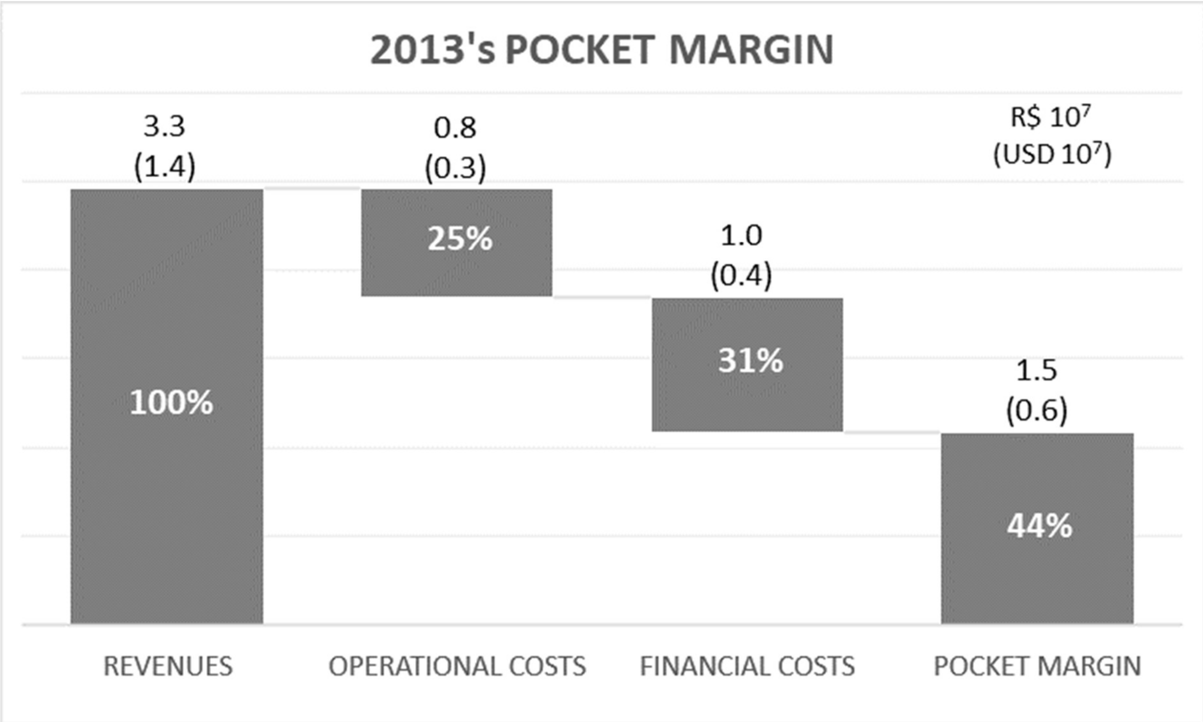

Figure 3.1.2. Pocket margin

Operational costs would take 25% from gross revenue, where fixed costs (or expenses) would be 94% of the total, and HR component is the most important representing 66% from it (see **Figure 3.1.3**). On the other hand, the MRSP would have more than 10.6 thousand new formal jobs.

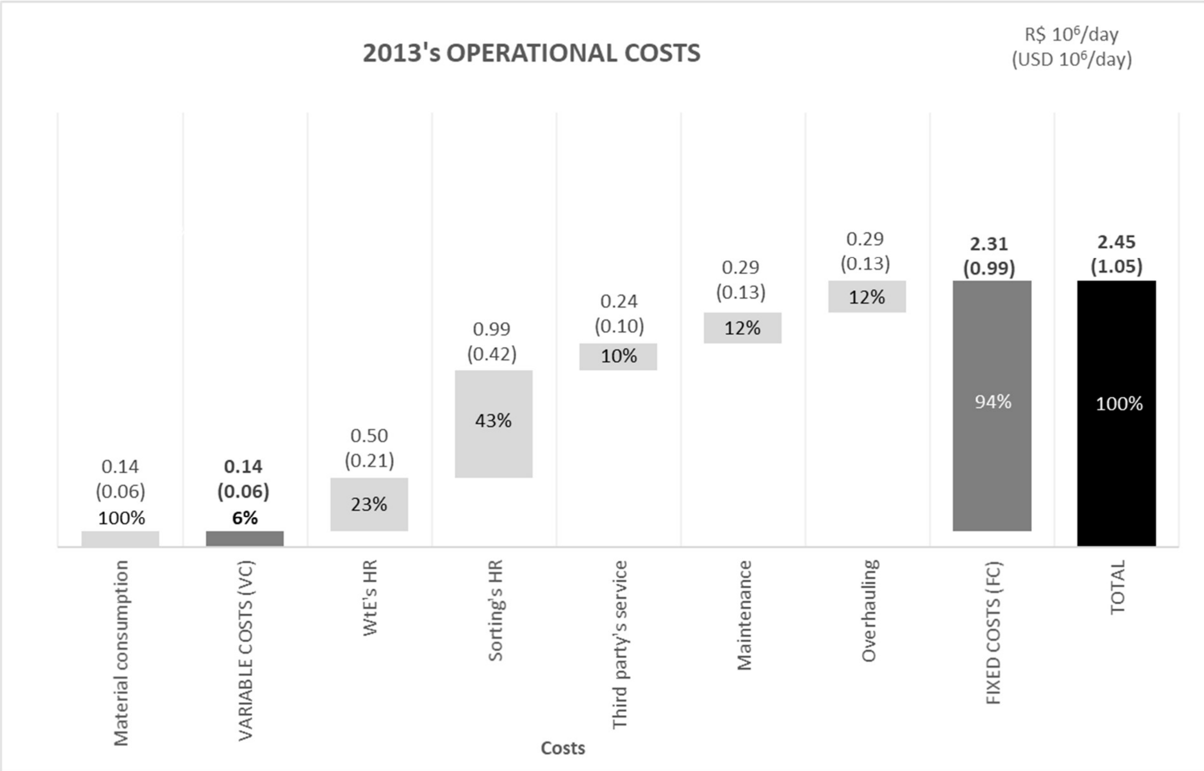

Figure 3.1.3. Operational costs' breakdown for 2013

Financial costs demanding 31% of gross revenue would have tax payment as the heaviest variable, or 62% of their total (see **Figure 3.1.4**).

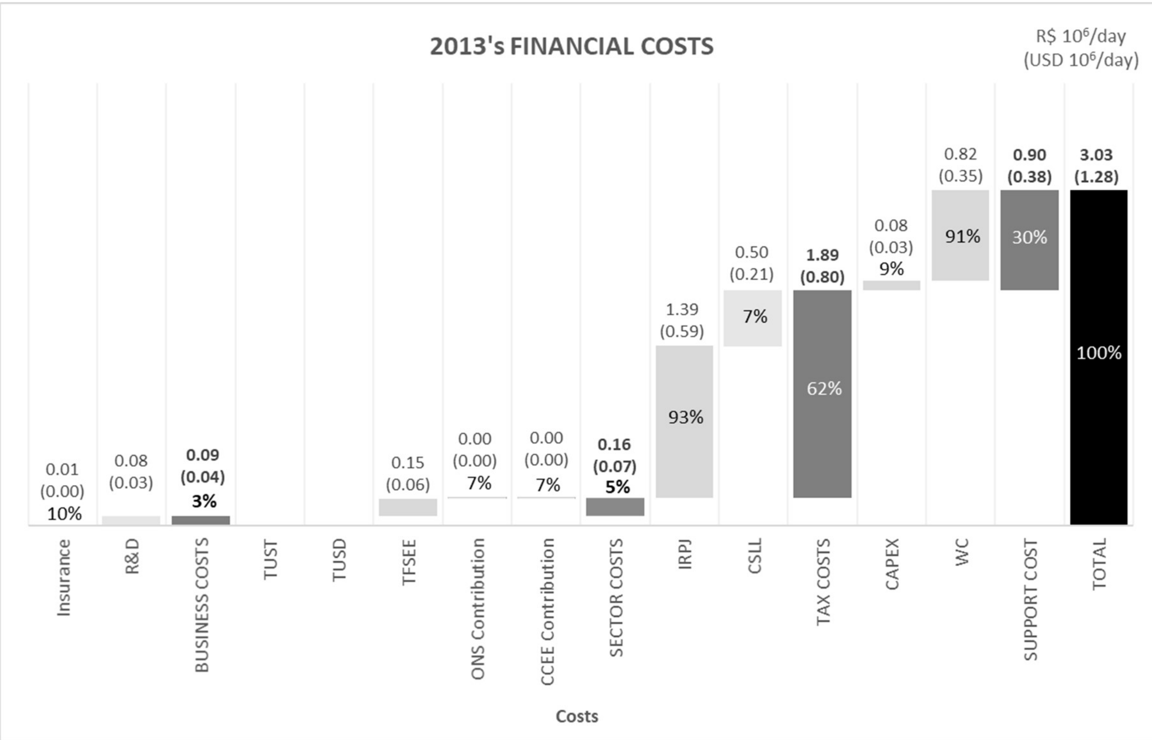

Figure 3.1.4. Financial costs' breakdown for 2013

The risk analysis was performed using 10,000 aleatory scenarios, built with records from the last ten years. Considering a confidence interval of 99% (means only 50 lower and higher values discarded from 10,000 ones), the variables IRR, NPV and PAYBACK using cash flows of 20 years would be as shown in **Figure 3.1.5**, **Figure 3.1.6** and **Figure 3.1.7** as a normal distribution with 99% of confidence interval (mean ± 3 standard deviations).

In average, IRR calculated would be 33.7% per year for the cash flow of 20 years considering constant currency. Negative and positive scenarios, based on records from the last twenty years, would give 16.5% as the lowest IRR, and 50.9% as the highest one (**Figure 3.1.5**). Considering the average hurdle rate of 6.2%, the calculated average IRR would be 5.4 times higher than it.

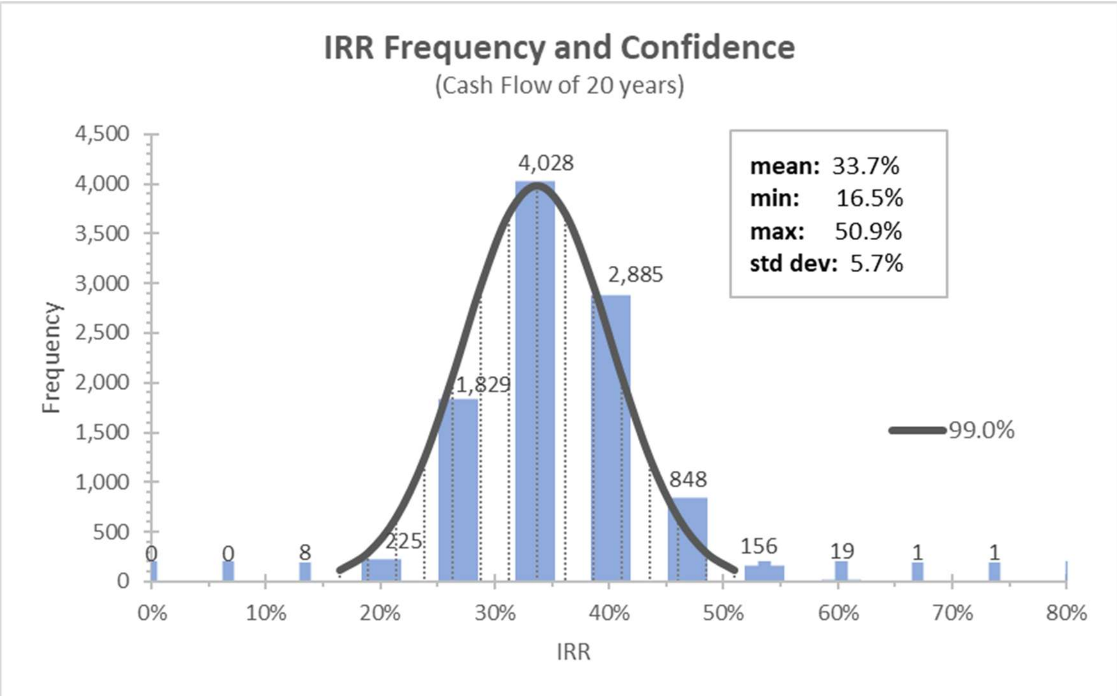

Figure 3.1.5. IRR analysis with a 99% confidence level

Value generation, assumed here as NPV, would present average value of R$ 10.8 (or USD 4.3) billion, or 68% higher than the worst scenario of investment mentioned in **Table 2.1.4.1**. Taking into account negative and positive historical scenarios, the model would create a minimum of R$ 2.1 (or USD 0.9) billion, almost 36% of the average amount of investment, and 334% for a maximum NPV of R$ 19.4 (or USD 7.8) billion (see **Figure 3.1.6**).

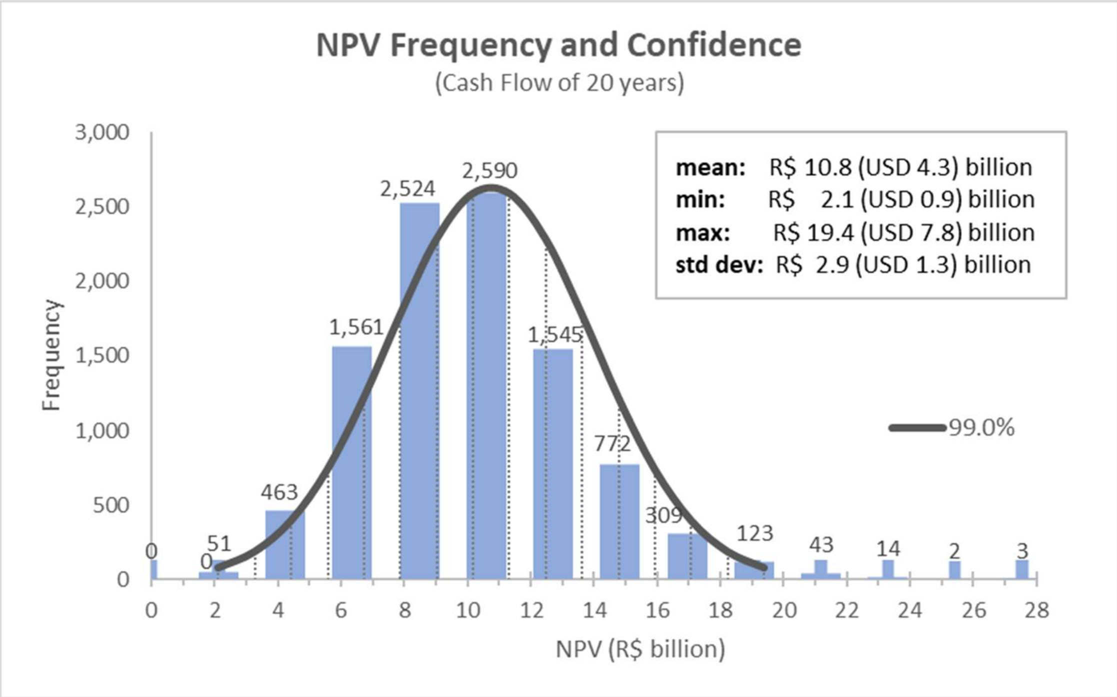

Figure 3.1.6. NPV analysis with a 99% confidence level

Analyzing the payback, the average time to pay the investment under conditions assumed in this study would be 6.6 years (**Figure 3.1.7**). For the best and worst scenarios, the range calculated would be from 4.4 to 8.8 years.

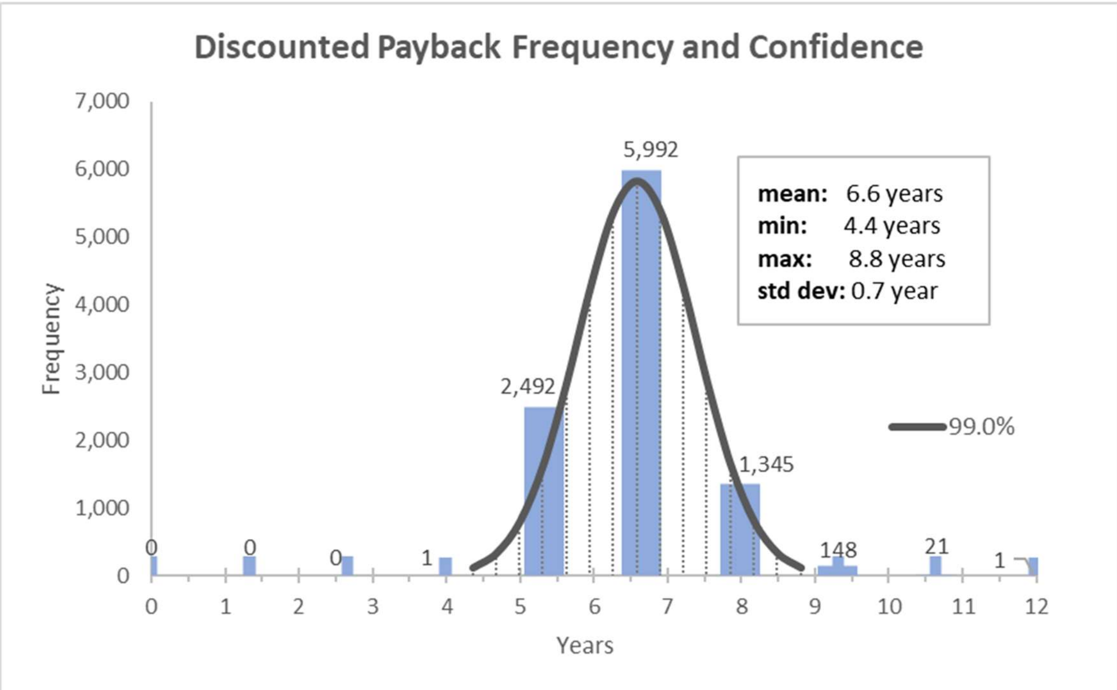

Figure 3.1.7. Payback analysis with a 99% confidence level

The proposal presents an average ROI (Return of Investment) of 24.5% per year (see **Figure 3.1.8**). However, even considering the lowest possible value of 7.9% per year, it would be higher than the highest hurdle rate of 7.5%.

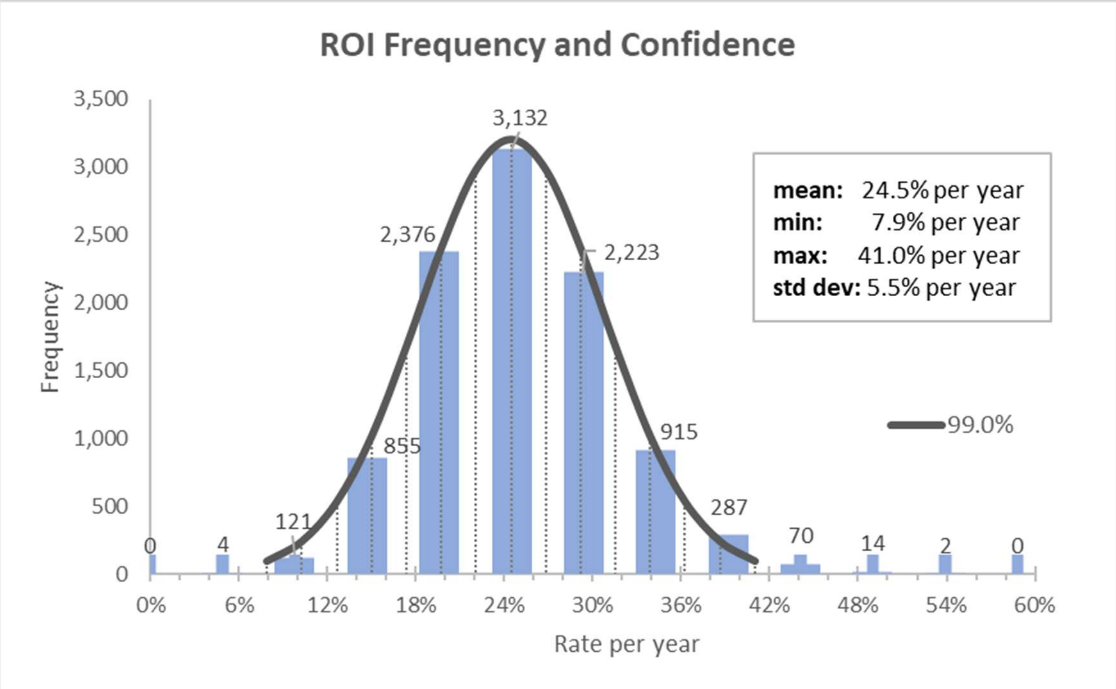

Figure 3.1.8. ROI analysis with a 99% confidence level

Assuming 2013´s market records, just to a cross-check, the model would delivery an IRR of 32.6%, NPV of R$ 12.9 (or USD 5.5) billion, and a payback of 5.5 years, fitting perfectly within the confidence interval. However, if the entrepreneurs decide to get BNDES's funding for sanitary ventures, the IRR could reach 116,3%. The value generation (NPV) would be R$ 13.4 (or USD 5.8) billion, and a payback of 6.9 years. ROI would be 22.9% in both cases but considering maximum BNDES funding of 80%; the ROE (Return on Equity) would be 95,8% per year to the investors (see **Table 3.1.1**).

Table 3.1.1. Comparison of equity versus funding (20 year's cash flow)

VARIABLE	100% EQUITY	80% of BNDES's FUNDING
IRR	33.7%	116.3
NPV	R$ 10.8 (USD 4.3) billion	R$ 13.4 (USD 5.8) billion
PAYBACK	6.6	6.9
ROI	24.5% per year	22.9% per year
ROE	24.5% per year	95.3% per year

It is possible to find some initiatives of landfills generating electricity with gas, but their references to the economic viability are pretty difficult to access in Brazil. ABREU and PICANÇO presented in their researches economic viabilities to landfills with gas recovering considering market fees (waste disposal service), prices (electricity) and efficiency on gas recovering and conversion to energy. By them, landfills with gas recovering presents IRR in a range from 16% to 36% and an ROI from 2 to 5% (ABREU, 2009; PICANÇO et al., 2011).

Once more it is important to emphasize that this work does not seek to demonstrate the financial and economic viability of the WtE facility. As pointed out in other studies, such as the FEAM or EPE, if considered only WtE units to treat the MSW, there are not encouraged conditions to propose an alternative to the landfills (EPE; MME, 2008; FEAM, 2012). The reasons are multiples, such as high investment, poor waste (low LCV and high humidity) and an energy market without encouraging prices. Here, as seen in articles already mentioned, the WtE technology (or other expensive existing technology) would be part of an integrated high-scale line for MSW treatment. The most important for reaching the economic viability would come from the sales of recoverable materials, such as plastic, fertilizer, paper, metal (mainly aluminum) and glass, and from the waste treatment service supplied by the MBT+WtE model to the municipalities. Using an RDF with an LCV improved by the MBT, the WtE facilities would be smaller and more efficient what would close the portfolio with their electricity revenues.

3.2 INTERREGIONAL INPUT-OUTPUT SIMULATION

The model presented in this article was fed with the inter-regional economic transactions of 62 sectors and 116 products shown in Use (U) and Make (V) matrices estimated by GUILHOTO and updated by the author to the year 2013, based on IBGE.

Impacts in the regional economy come from the introduction of the MBT+WtE sector treating 100% of MRSP's MSW in 2013, and their results presented under direct and indirect effects into the region, state, and country.

The subsection 3.2.1 shows and discusses the results from the socioeconomic point of view through the impacts on Production Value (X), Jobs and Gross Domestic Product (GDP).

Estimated new environmental and energetic scenarios discussed in section 3.2.2 where Greenhouse Gases (GHG) and Energy Consumption results face the operation of the MBT+WtE sector at MRSP.

3.2.1 SOCIOECONOMIC IMPACTS

According to the model, where it is considered to establish an MBT+WtE sector at MRSP, the effects over the regional economy would be, predominantly, indirect ones (see **Table F 1**).

The metropolitan's GDP would increase by 0.2% keeping the same level of production value in 2013 (see **Figure 3.2.1.1** and **Figure 3.2.1.2**). The new sector would be responsible for adding value to the local economy by itself, and demanding local services from sectors **S40 –** ***Electricity, Gas, Water, Sewage and Urban Cleaning*** (+ 0.1%) and **S47 –** ***Maintenance and Repair Services*** (+ 2.7%) to keep its 12 facilities working. On the other hand, reduced values from sectors related to cleaning services, organic compost, and recyclables. The sectors would be **S62 –** ***Urban Cleaning Services*** (-49.8%), **S5 –** ***Other from Extractive Industry*** (-12.3%), **S17 –** ***Resins and Elastomers Production*** (-5.8%), **S58 –** ***Production of Paper, Cardboard and their Products*** (-5.2%), and **S57 –** ***Non-Metallic Minerals Extraction*** **(-3.0%)** (detailed in **Table G 1** and **Table H 1**).

Another sector strongly impacted would be the **S61 –** ***Electricity Production*** (fuel oil-based). Considering a total installed capacity of 504 MW and selling energy cheaper than the fossil fuel-based one commonly dispatched in drier periods, the new sector would decrease by 25% the demand for a thermoelectric generation in São Paulo State or 2% in Brazil. This thermoelectric fuel oil-based demand occurs in dry periods of the year when the hydro sources are not working at full capacity. The amount of electricity would be enough to cover 100% of the State's demand for public lighting.

Both, rest of São Paulo State and Brazil would have their GDP and production value decreased by 0.15% and 0.20%, respectively, the recyclables replacing "virgin" raw materials.

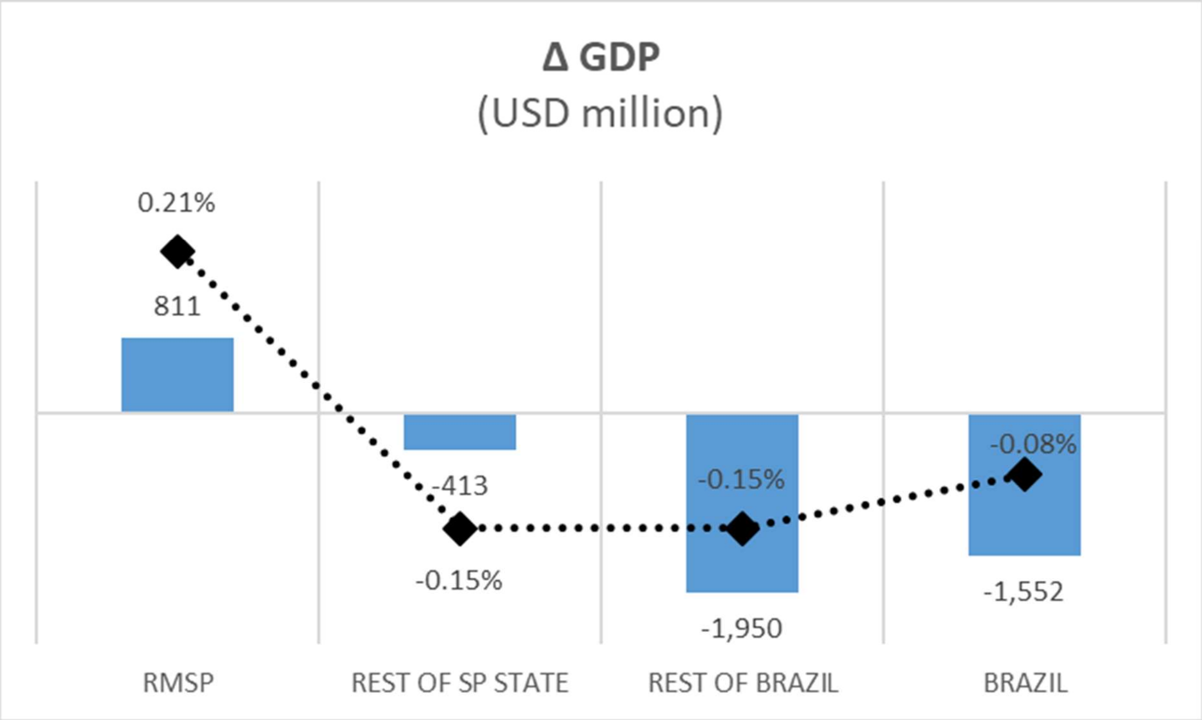

Figure 3.2.1.1. GDP impacted in 2013

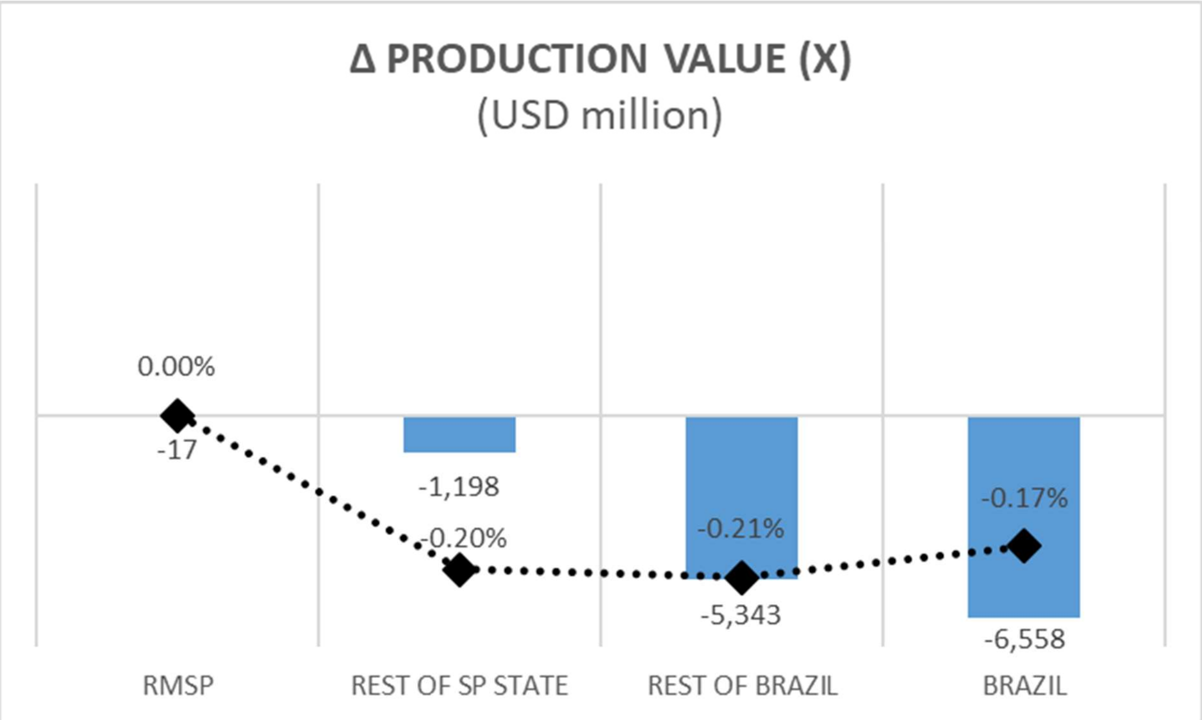

Figure 3.2.1.2. Production Value impacted in 2013

The MBT+WtE sector would demand 10,678 job opportunities to attend the MRSP. This new sector would represent an increment of 10,559 jobs (+0.08%) taking account, approximately, the total of 12.6 million current ones (see **Figure 3.2.1.3** and **Table I 1**). Sectors producers of Papers and Plastics would be slightly impacted (-0.50% or 219 jobs) despite being more efficient than recyclables collection's supply from the new sector. On the other hand, demanded services (i.e., maintenance to recycling and WtE assets) in the local economy represented by the sector **S47 –** ***Maintenance and Repair Services*** would have +0.19% (or 562) job opportunities.

The impact in the rest of São Paulo State would be less 691 jobs or -0.01% of the total 9.8 million opportunities. The sectors most impacted would be those who produce Papers and their Forestry raw material with almost -0.4% (or 254) jobs.

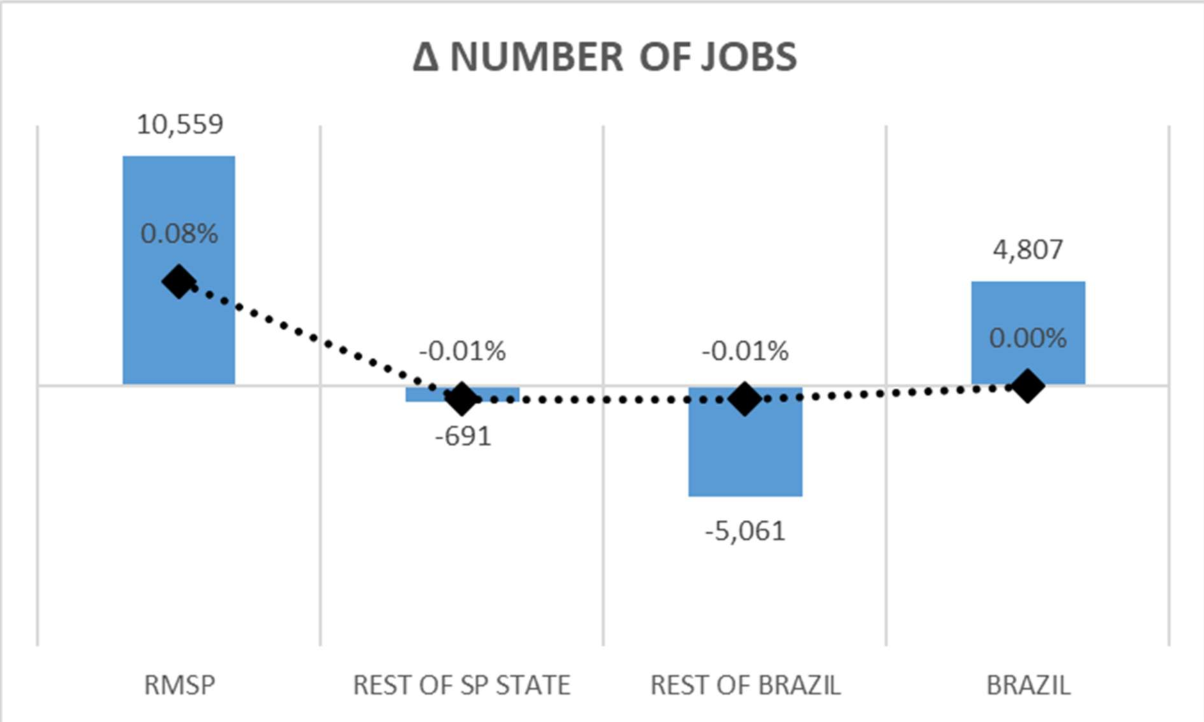

Figure 3.2.1.3. Number of Jobs impacted in 2013

In the rest of the country, the indirect effect of MRSP's new sector on the losses of jobs would be even higher in absolute numbers (-5,061 jobs), or -0.01% of the total, approximately, 80.0 million ones. In this case, the sectors with more significant losses would be those who produce Paper, Non-Metallic Minerals Extraction and Services decreased by recyclables' supply.

However, nationally speaking, the new MBT+WtE sector working at MRSP would increase up to 4,807 jobs in 2013.

3.2.2 IMPACTS ON ENERGY CONSUMPTION AND GHG EMISSIONS

Based on Energy Consumption and GHG Emissions' inventories already presented in the subsection 2.2.2, and submitted to the I-O model proposed in this article, the MRSP would have a reduction of 0.31% in its energy consumption. The GHG emissions would have a decrease of 3.4% (or 2.993 Mton CO_2 eq), as shown in **Figure 3.2.2.1** and **Figure 3.2.2.2**. That would be the answer given by the indirect effect of the new sector. It would offer MSW treatment (alternative to landfill and without releasing CH_4), electricity produced with RDF (alternative to oil-based), recyclable raw materials (metal, plastic, glass, and paper) and organic compost (fertilizer).

Less energy consumed when replacing the use of "virgins", fewer greenhouse emissions when reducing raw materials consumption, and choosing release CO_2 instead of CH_4 within WtE process.

In **Table J 1** is shown that the sectors that most contribute to the reduction of energy consumption would be the **S58 – *Production of Paper, Cardboard and their Products***, **S17 – *Resins and Elastomers Production*** and **S61 – *Electricity Production*** (fuel oil-based).

It is also possible to verify an energy consumption reduction of 0.3% in both regions, the rest of São Paulo State and the rest of Brazil. The highlight to the significant contribution of the sector **S58 – *Production of Paper, Cardboard, and their Products*** depends on the production localization and the weight of their energy consumption level in the economy.

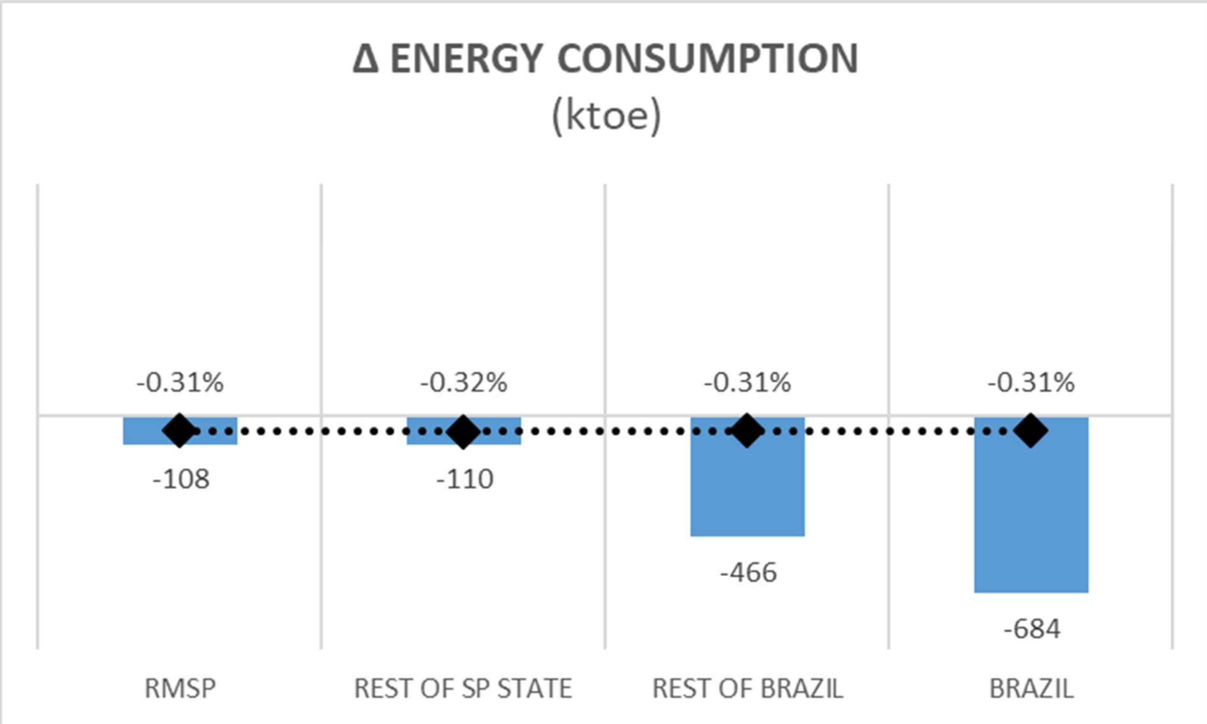

Figure 3.2.2.1. Energy consumption impacted in 2013

In **Table K 1** it is possible to note the model points to GHG emission reduction in the MRSP, mainly by the **S62 – *Urban Cleaning Services*** (-95.4%). Indeed, the result is due to the choice of the new MSW treatment without emission of CH_4. In the rest of São Paulo State and the rest of Brazil, the reduction of GHG emissions would be by 0.2% and 0.1%, respectively.

GHG releases in all Brazilian territory would be by 0.3% due to the direct and indirect effects of the new sector. Avoided dispatch of fossil fuel-based electricity could be considered an additional contribution to the decrease of GHG emissions, especially in dry weather periods of the year when the hydro source is not enough to support the demand.

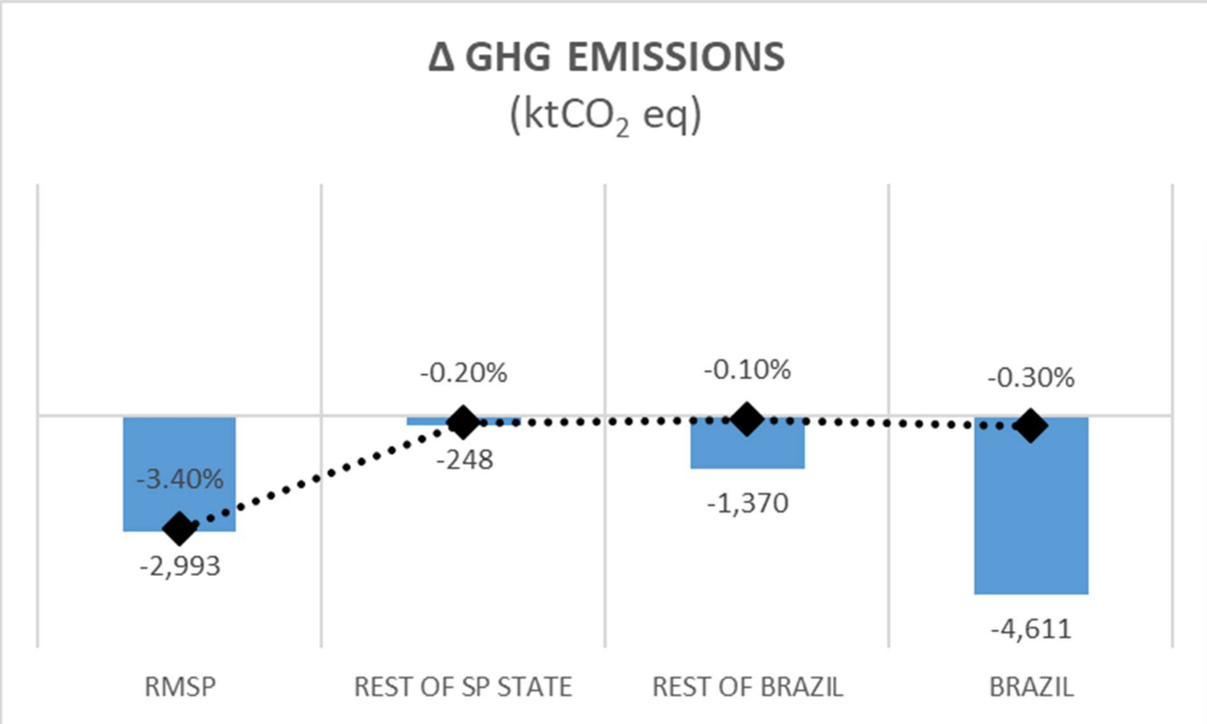

Figure 3.2.2.2. Emissions impacted in 2013

3.3 Public Policy Improvement

As established by the PNRS, 100% waste generated in Brazil would be destined to landfills from 2014. Despite penalties imposed on municipalities who do not comply with, entities, such as the Brazilian Association for Public Cleaning and Special Residues' Companies (ABRELPE), are warning in all their reports that they are neglecting this challenge (see **Figure 3.3.1**) (ABRELPE, 2016).

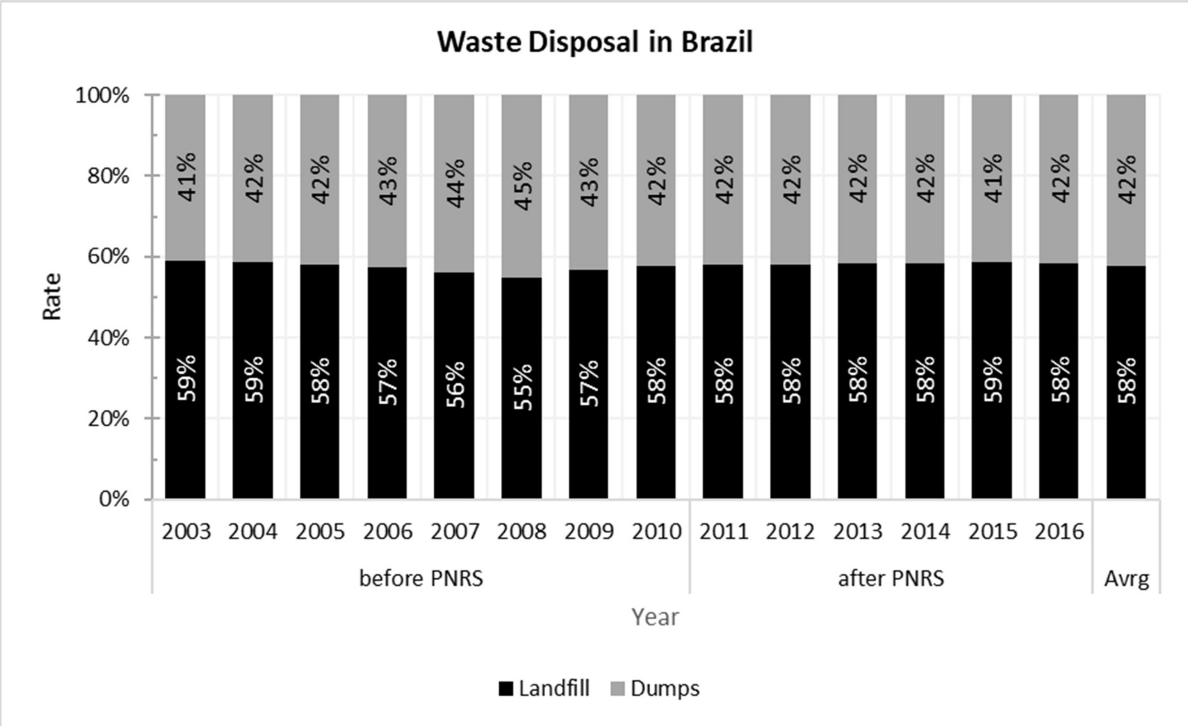

Figure 3.3.1. Waste Disposal in Brazil
Source: Data compilation from ABRELPE (ABRELPE, 2016)

Unfortunately, it is clear to verify that dumps remain as a destination for waste since 2003, without or a few progress on landfills' services. Level of investment on sanitary services does not seem to be the main reason not to achieve dumps eradication, even considering that it is tough to manage it within a budget with ±50% of deviation from 2007 to 2015. On average in this period, Brazil had USD 14 per capita-year of investment which should be used to treat almost 1.2 kg (or 2.3 pounds) per capita-day of waste. This amount was equivalent to what EU-28 invested with the practically double amount of waste produced (see **Figure 3.3.2**).

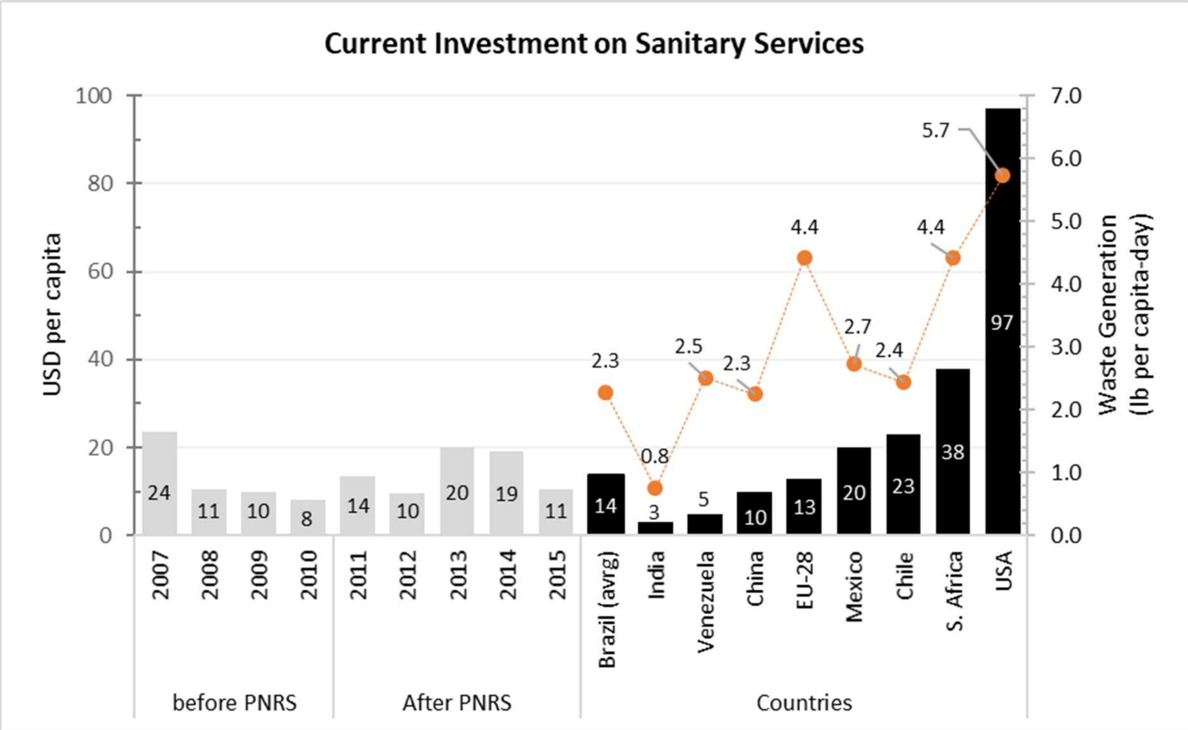

Figure 3.3.2. Investments in Sanitary Service
Source: Data compilation from ABRELPE (ABRELPE, 2016) and The World Bank (HOORNWEG and BHADA-TATA, 2012)

So, what would be the possible reason for not achieving the same European results? The answer seems to be found in **Figure 3.3.3**, below. Both, USA and Europe have a matrix of destination with more than one solution, what is favorable to use multiple strategies and to accomplish achievable challenges and goals. Considering a more resilient infrastructure is possible to mitigate the usage of land, where availability is a problem in metropolitan regions, save resources with recycling, produce organic fertilizers with organic composting and generate energy (electricity and steam) with the thermal process. As an example, in his most recent article, YILI has pointed out a comparison where waste-to-energy plants are 127% more efficient than landfills, but not all regions of China could have enough demand to justify a higher investment (YILI et al., 2017).

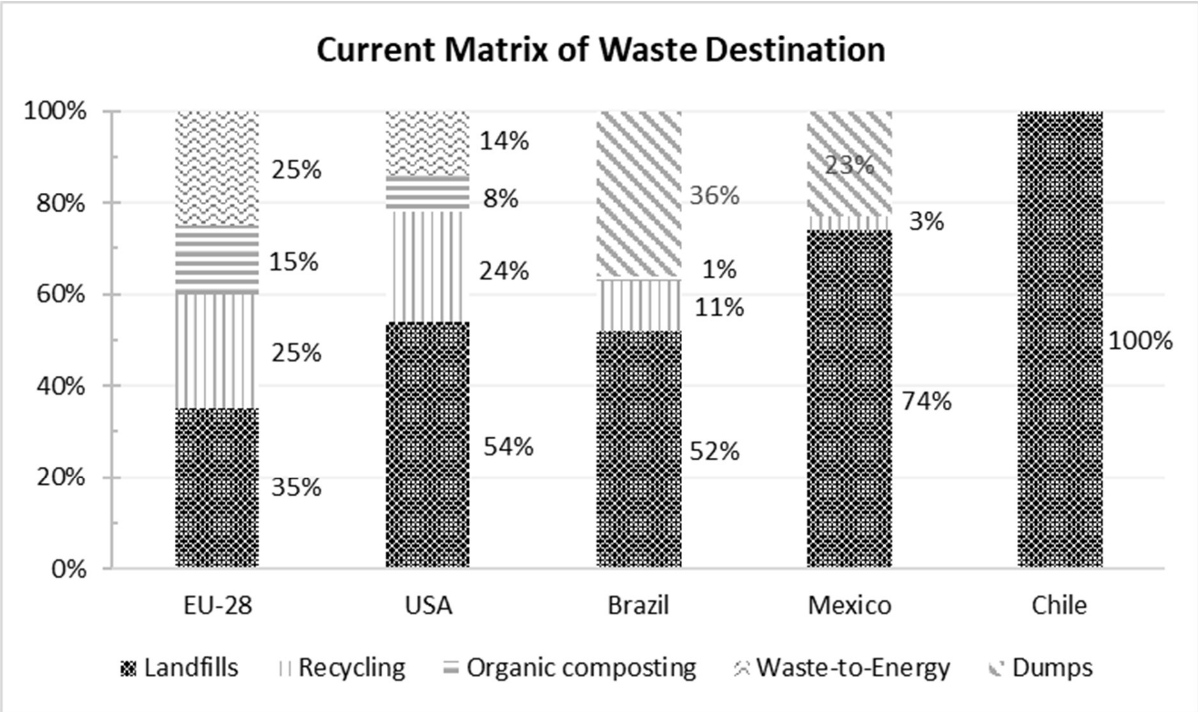

Figure 3.3.3. The matrix of Waste Destination
Source: Data compilation from ABRELPE (ABRELPE, 2016) and The World Bank (HOORNWEG and BHADA-TATA, 2012)

Even having recycling in its matrix of treatment, Brazil still shows only 11% of waste recycling rate, thanks to the high rate of aluminum recycling. While PNRS established 20% by 2015, this insufficient rate comes due to the level of organics and other (mainly electronics) represent no more than 1% of their amounts found in municipal residues. Especially at organic ones, it is strange to face that developing countries, where people are still starving, have their waste with up to 70% of the rest of the food. And not only in Brazil, but this also happens with the too low rate of recycling, or organic composting. YUNMEI presents in his article that China dropped its rate of organic treatment from 10% to 2% in the last 15 years, in contrast with what is happening in Europe where this rate rounds 15% and raising from time to time (YUNMEI et al., 2017).

Plastic's rate (11%) is also low in comparison with paper and glass (46%), or even if compared with steel and aluminum ones (99%), shown in **Figure 3.3.4**.

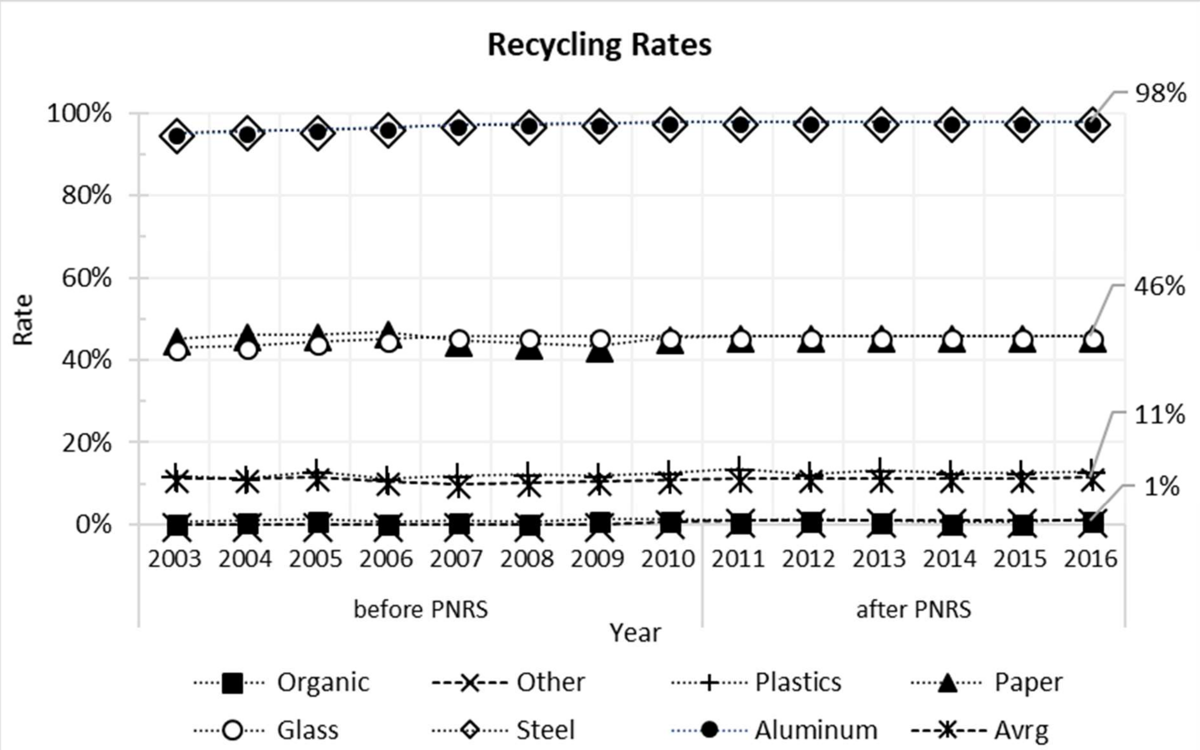

Figure 3.3.4. Record of Brazilian recycling rates
Source: Data compilation from ABRELPE (ABRELPE, 2016) and IPEA (IPEA, 2012)

Another critical issue comes from the fact of PNRS has not achieved 100% cities engagement's goal. Despite growing more than 137% since 2002, the engagement's rate only reached 19% after six years from the policy's establishment (see **Figure 3.3.5**).

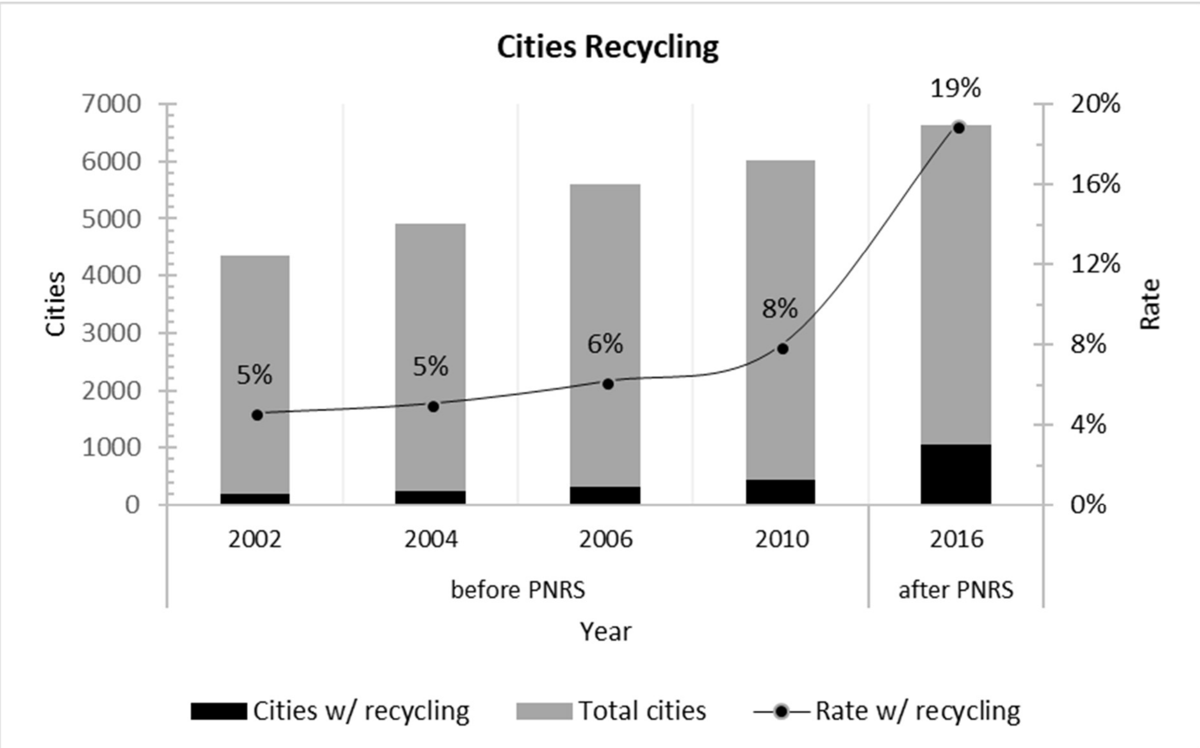

Figure 3.3.5. Cities recycling
Source: Data compilation from ABRELPE (ABRELPE, 2016) and IPEA (IPEA, 2012)

Steel and aluminum rates of recycling seem to be a solved problem in the Brazilian MSW management, and yes, the reason comes from the commodities' high value per weight. In these examples are possible to see an organized work between society and producers. One considers the possibility of an extra-income for families and other, an opportunity to reduce production costs with raw materials and, mainly, energy.

However, what to do with other commodities, such as paper, glass, and plastic? Are they within the optimal rate of recycling?

This analysis must follow their possible applications in the market, and package one must be the focus due to its disposable, or short shelf life, characteristic.

These materials have low value per weight and interests in recycling them are equally low for society and producers. Moreover, sometimes, even in developed countries, where recycling seems to be under control, the prices of these recyclable commodities are too low that can compromise the whole system, as mentioned ROGOFF is his article (ROGOFF and ROSS, 2016).

Over these aspects, the pneumatics' program could be a good benchmark case to reproduce and encourage better rates of recycling, even known their reverse logistics is the capital response to the success.

An excellent initial parameter to take is the rate of disposal application of each material, or what fraction of it goes to attend the market of packaging (see **Figure 3.3.6**, **Figure 3.3.7** and **Figure 3.3.8**).

In the case of plastics, the rate is 81%, with a standard deviation of ±7%, due to several types used for packaging and each one has own fraction of destination to a disposable application. For example, frequently more than 30% of all PE produced is for packaging purposes. In cases like PS and PET usually, are used 100% to attend the market of disposables. PVC most used in the past, but now less than 10% goes to this market which is accompanied by PE and PP (30%), mainly with flexible films and injected or molded containers.

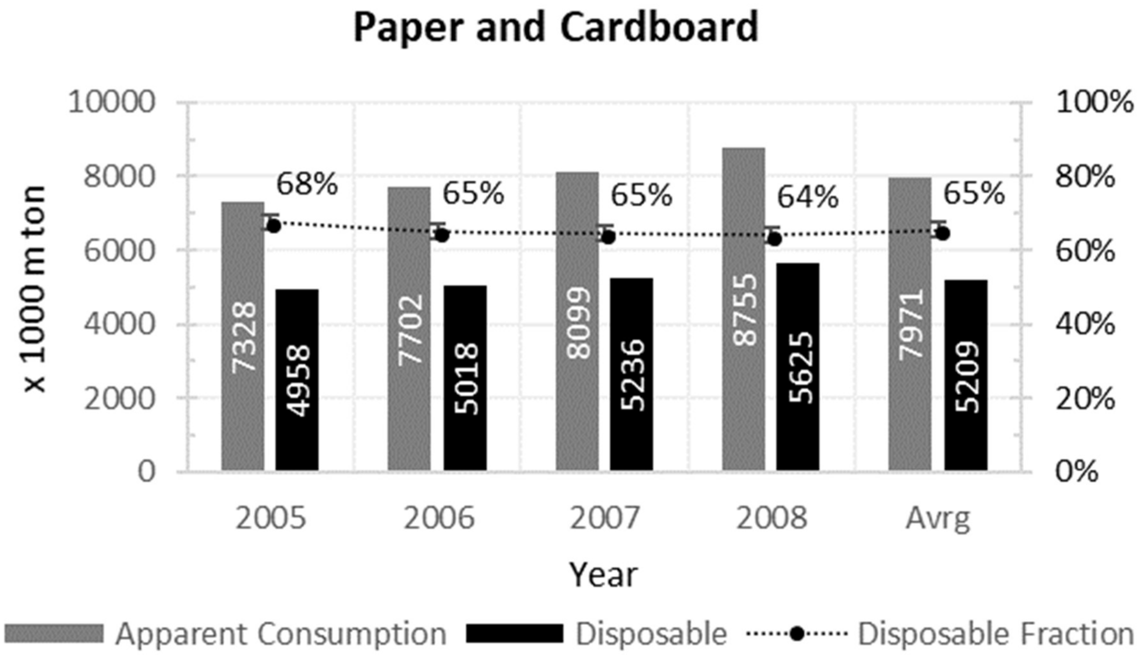

Figure 3.3.6. Disposable fraction for Paper and Cardboard
Source: Data compilation from ABRE (ABRE, 2017) and ABTCP (ABTCP, 2016)

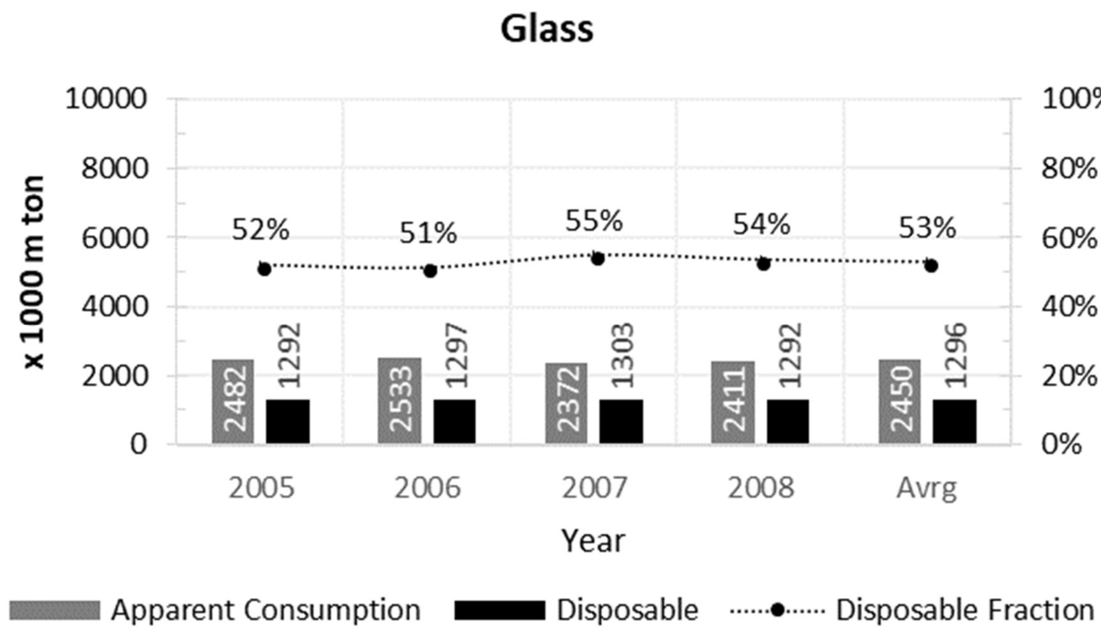

Figure 3.3.7. Disposable fraction for Glass
Source: Data compilation from ABRE (ABRE, 2017) and ABIVIDRO (ABIVIDRO et al., 2016)

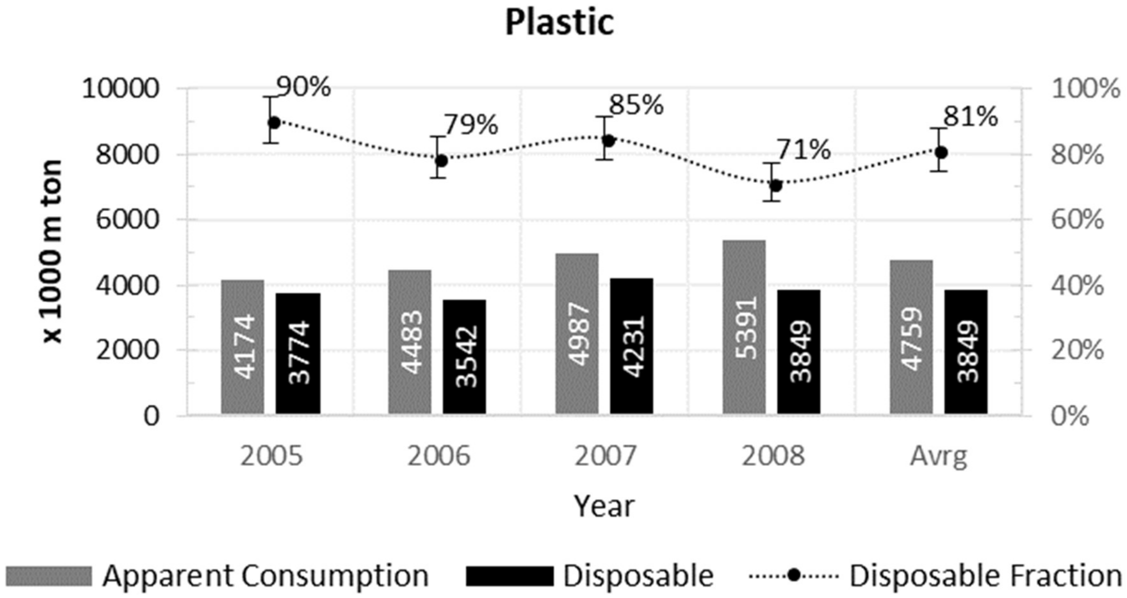

Figure 3.3.8. Disposable fraction for Plastic
Source: Data compilation from ABRE (ABRE, 2017) and ABIQUIM (ABIQUIM, 2015)

As an open market with local and foreigner players, another important parameter is the market share to attribute responsibilities and goals. **Figure 3.3.9** shows the most recent apparent consumption and own domestic production, import and export amounts for each material.

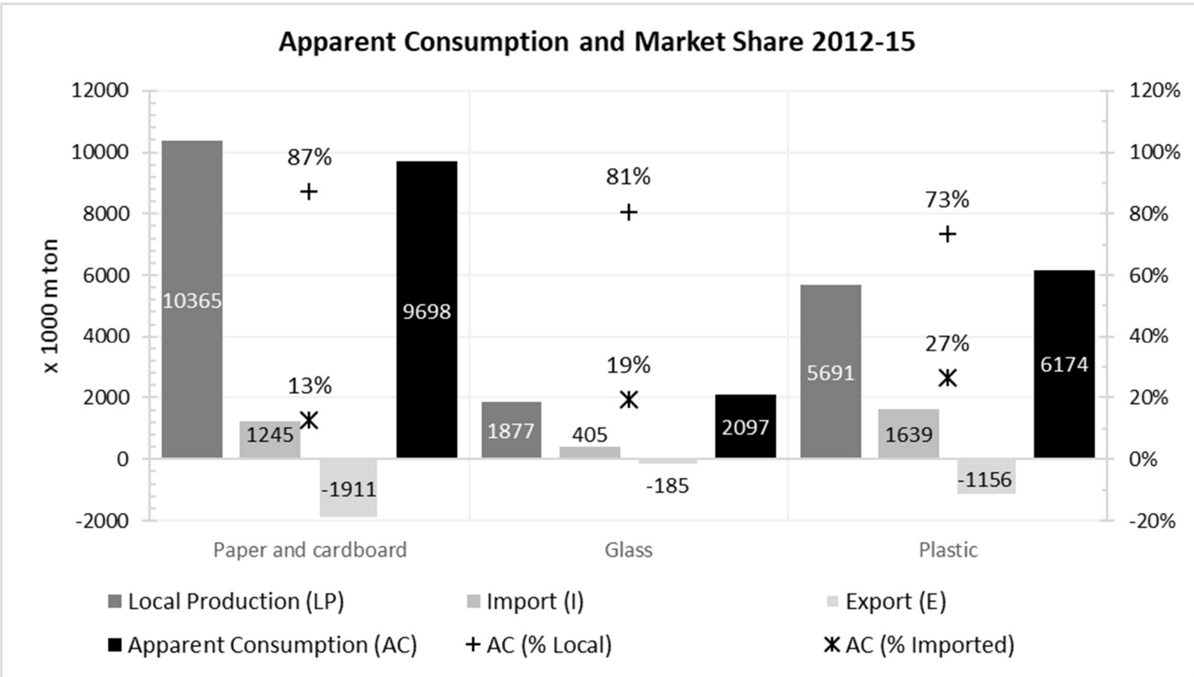

Figure 3.3.9. Apparent Consumption and Market Share
Source: Data compilation from ABRE (ABRELPE, 2016), ABTCP (ABTCP, 2016), ABIVIDRO (ABIVIDRO et al., 2016) and ABIQUIM (ABIQUIM, 2015)

The apparent Brazilian consumption for paper and glass is more than 80% supplied by local companies. In the case of plastic, 73% of it is local, and 27% comes from foreigner companies.

That means each category of material (paper and cardboard, glass and plastic) must have its current market suppliers responsible for their share. Despite several players in each category, organization and information management is not a problem. All have their specific institute or association, such as Brazilian Technical Association of Automatic Glass Industries (ABIVIDRO), Brazilian Association of Chemical Industries (ABIQUIM) and Technical Brazilian Association of Pulp and Paper (ABTCP) (ABIQUIM, 2015; ABIVIDRO et al., 2016; ABTCP, 2016). These entities can supply all information about the amount produced, exported, and material destination in the local market. In the case of imported materials, RFB (Brazilian Federal Income Bureau) can track their players and movements through their NCM (Common Mercosur Classification) (RFB, 2018).

Using the equation (E. 25), considering data from **Figure 3.3.6**, **Figure 3.3.7**, **Figure 3.3.8** and **Figure 3.3.9**, is possible to calculate a minimum average recycling rate for materials (see **Figure 3.3.10**) and a new minimum national goal for Brazilian's policy (see **Figure 3.3.11**).

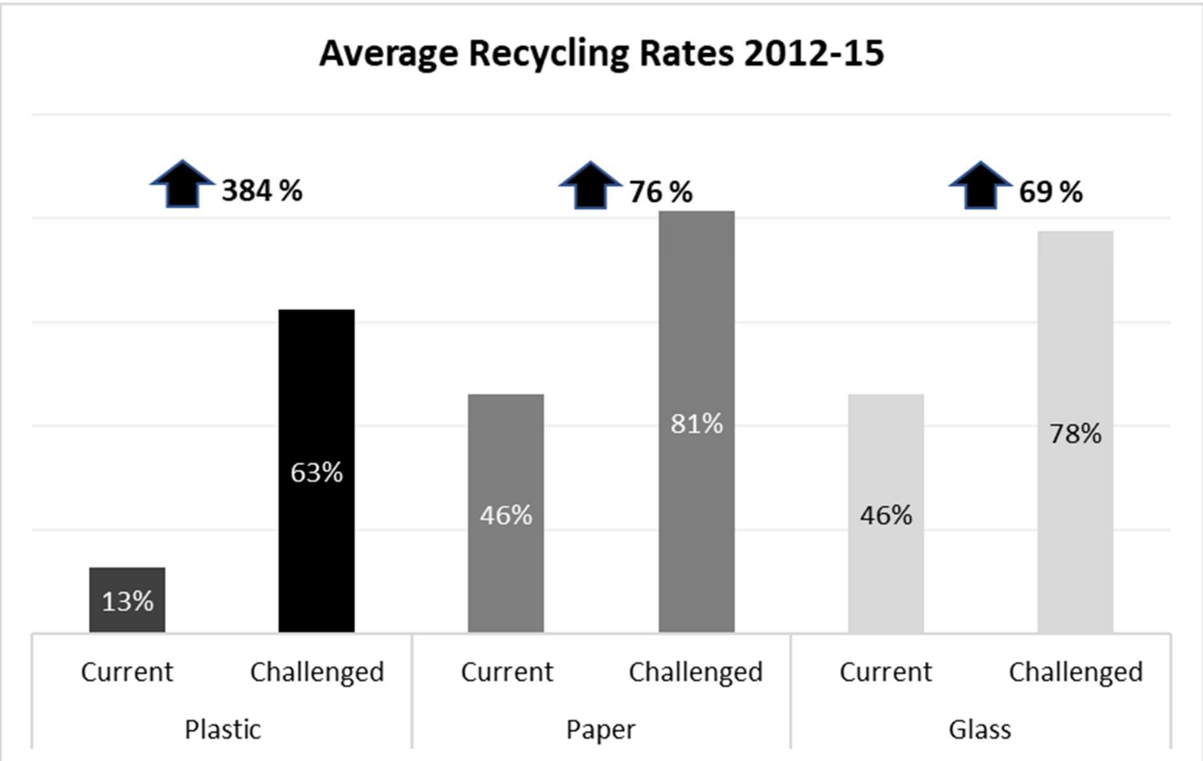

Figure 3.3.10. Challenged recycling rates for recyclables
Source: Author's calculation

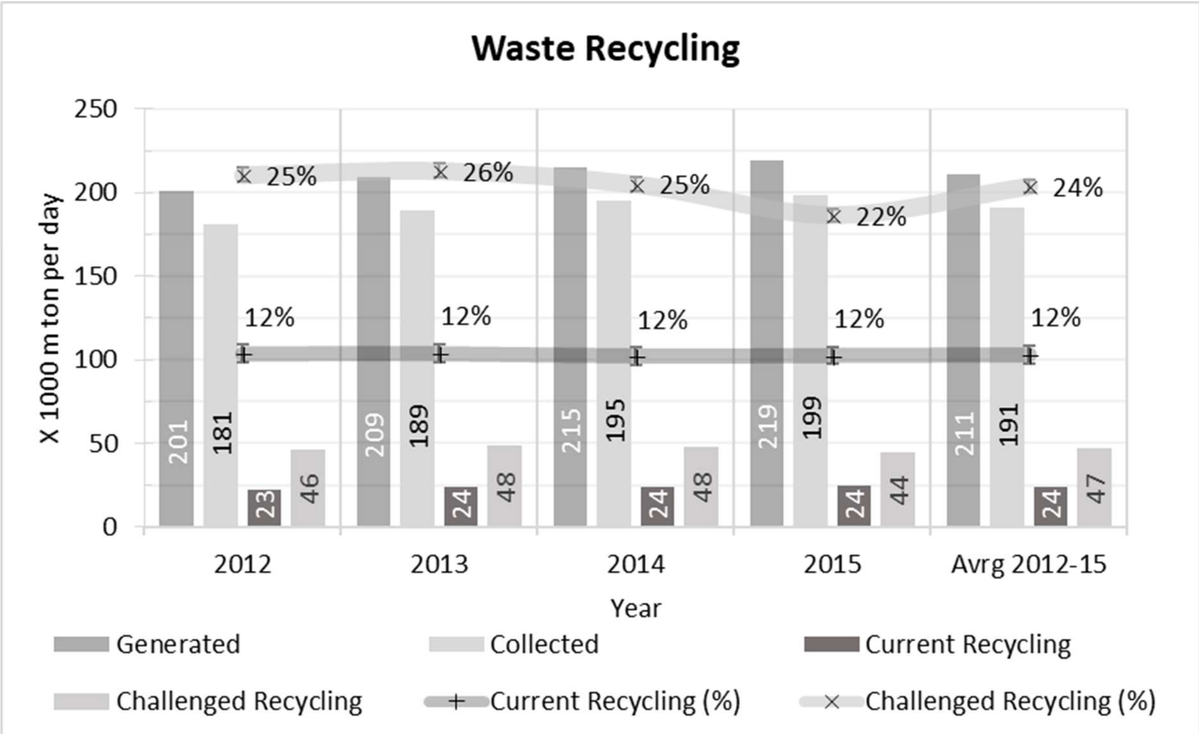

Figure 3.3.11. Comparison of current versus challenged recycling rates
Source: Author's calculation

A disposable factor is possible to define a realistic minimum rate of recycling. In the case of plastic, its rate could jump from the current 13% to 63%, representing a growth of almost five times. Even glass and paper with their 46% of recycling rate could reach approximately 80% on average.

The national rate of recycling could be twice higher than the current one and reach a level found in developed regions like Europe and the USA.

An advance in this proposal is to allow how to track what is weighing more in a category (e.g., plastic) with multiple materials. **Figure 3.3.12** shows a breakdown based on the application's market share for most used plastics.

Most found plastic in the waste, PET (42%) must be challenged to recycle at least 26%, mainly the bottle grades, due to your volume and the ease of recycling because it is cleaner than containers.

The biggest challenge is within polyolefins (PEAD, PEBD, and PP). Together, they represent 55% of all plastics discarded as films, vessels, containers, bags, and 35% would be a minimum rate for them.

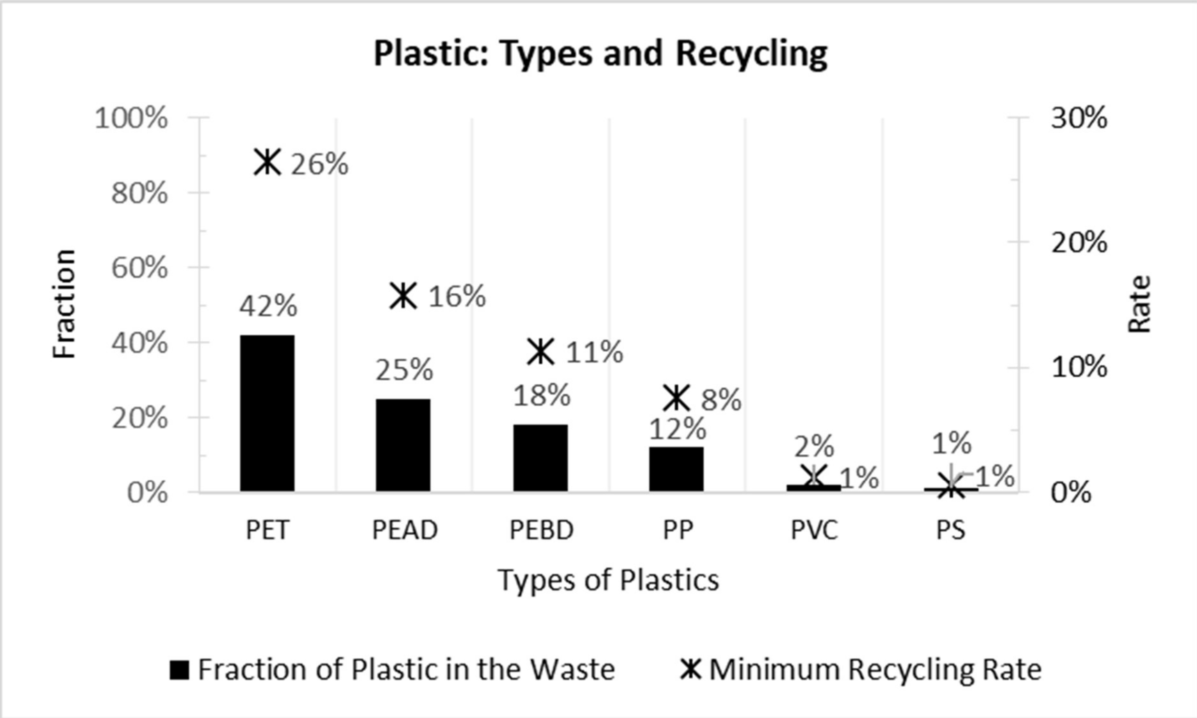

Figure 3.3.12. Plastic: Types and Recycling
Source: Author's calculation

With this recycling rate breakdown is possible to know who must be charged to accomplish its calculated goal. Moreover, as EPA has done in the USA, IBAMA could be in charge of monitoring these categories and their players, making annual reports to ME (Ministry of Environment). This mechanism already works for managing discarded tires, and based on IBAMA's reports to ME, this one has all conditions to apply, when necessary, tax penalties to those companies, or their associations, who do not meet the goals.

CHAPTER 4. CONCLUSIONS

Most important issue when developing a proposal to manage the MSW is the presence of robust public policy. It is the start point that guarantees the compromise to solve the problem, and gives to the investors, public or private ones, a secure on what to invest. Public police like the PNRS should indicate multiple alternatives to technologies which could be able to dispose and treat the waste. It must not be restrictive because this does not give the opportunity to create a matrix of solutions to manage the MSW. As already shown before, a good example to Brazil is what developed countries have done mainly when having a well-structured recyclable collection. Considering multiples alternatives to treat their waste, they can choose the best one by the characteristics of their regions. Typically when they have enough space and a structured chain of recyclables collection, landfills are the way. If they are facing a high demographic region with too many environmental restrictions, such as water reservoirs and forest reserve, a most expensive or complicated solution can be an option. Mainly talking about the source of energy and emissions, the PNRS 12.305/10 must challenge the municipalities to increase their rates of recycling. Europeans already have recycling rates up to 67%, and they reached this significant level with robust public policy. Then, a proposal to the Brazilian policy which moves the current level of recycling from 12% to 24%, demanding producers engagement, does seem to be feasible to a start point, mainly to present a strategy to reverse logistic for recyclables; what pneumatics producers already solve it.

As shown in this thesis, a large-scale model of recycling and thermal waste treatment can reduce the demand for electricity (-0.31%) and carbon emission (-3.4%) in the MRSP. Choosing a model which can produce energy through the waste, the dispatch of electricity generated in fossil fuel-based thermoelectric plants can be avoided, mainly in dry periods of the year. An MBT model offering recyclables and power through the waste mitigates the demand for raw materials and their associated carbon emissions when produced. An alternative to the land-use can also reduce methane release which is more than 20 times worst to the atmosphere than carbon dioxide.

Locally the initiative shows a bonus of GDP increment to the MRSP with the proposed model. Its GDP increases (+0.21%) and job positions increase up to 10,559 new ones. Rest of the regions of Brazil would present a decrease of GDP and job positions due to the supply of recyclables. Their low demand of related services available in the economy, products and value in comparison with "virgins" materials can cause these impacts, but this could be improved if the current producers of new materials look to this massive supply of recyclables as an opportunity to add value. Moreover, this seems to start in the worldwide market with petrochemicals and paper producers joint-venturing with recyclers. They are figuring out niches of the market willing to pay better to have recyclables with supply and source confidence.

Even a model considering expensive technologies are liable to attend metropolitan regions like São Paulo. Recycling and extracting as much as possible of organics from the waste, reduce the capital intensity when investing in WtE units. Smaller units are necessary to produce electricity with more efficiency, and best values come from sales of service and products. In the case shown in this thesis, the model presents economic viability (e.g., IRR= 33.7% and ROE=24.5% per year) that would not be an obstacle to change the status quo of dumps, landfills and low engagement on recycling. By the way, this viability can be better (e.g., IRR=116.3%, ROI=22.9% per year and ROE=95.5% per year) with lines of financial credits with substantial interest rates. A good example is the National Bank of Economic and Social Development (BNDES), a Brazilian federal bank has a credit line for Environmental Sanitation and Water Resources with low-interest rates with a minimum 20% of investor's equity.

Breaking the paradigms of economic viability and negative social impacts, reducing the electricity demand with less carbon release, hopefully, this thesis contributes to improving the PNRS. It is essential to consider in it more technologies to manage the municipal waste, due to several different area characteristics, to increase the coverage of the policy's compromises, and to attract more investors and entrepreneurs.

As already detailed, domestic waste anaerobic digestion is not typical on an industrial scale as well as agriculture and livestock ones. Its residues composition with too many preservatives, demanding activation (e.g., use of degradation promoters) to accelerate the process of degradation and gas production, and assets too capital intensive, are still considered barriers to overcome. That explains why it is more common to aerate and dry it to produce organic fertilizer. Despite this, as far as this author researched and performed this thesis, he did not find any study taking into account all potential sources of revenues in an MBT with anaerobic digestion and WtE units what suggests an opportunity to future research even considering any financial and technical obstacles.

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APPENDIX A. Current MSW organization at MRSP

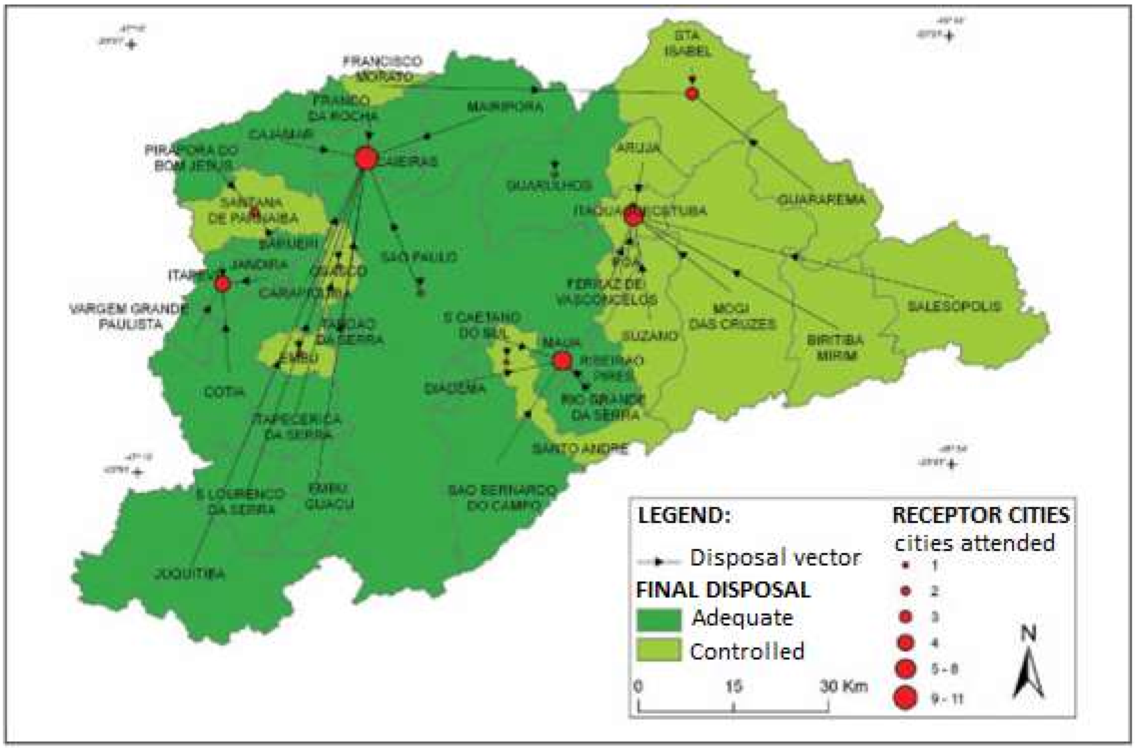

Figure A 1. MSW disposal´s map at MRSP adapted from JACOBI (JACOBI and BESEN, 2011) – color

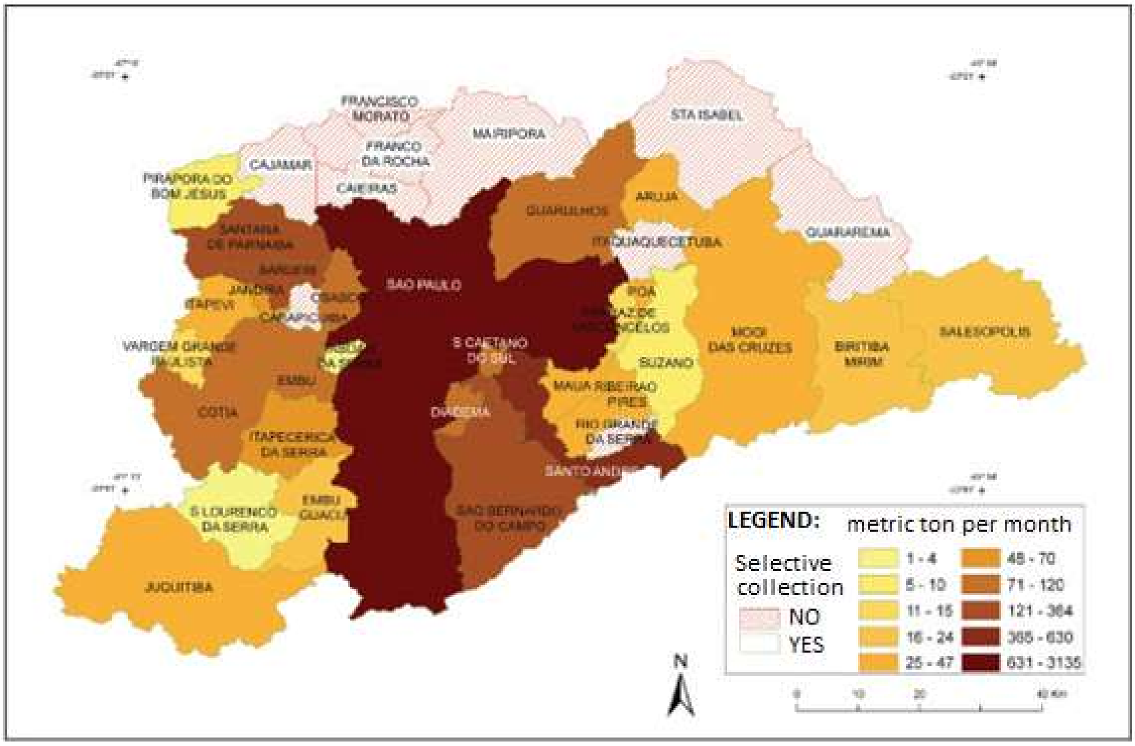

Figure A 2. Recyclables collection’s map at MRSP adapted from JACOBI (JACOBI and BESEN, 2011) - color

APPENDIX B. MSW´s gravimetric composition at MRSP

Table B 1. Gravimetric composition to the MSW at MRSP

MATERIAL	WET	DRY
	76%	24%
	GRAVIMETRY (%)	
Aluminum	0.46	1.2
Rubber	0.12	1.22
Styrofoam	0.27	0.21
Natural wood	0.71	0.07
Processed wood	0.13	0
Metal	0.58	1.59
Paper	4.97	16.14
Cardboard	2.58	10.71
PET bottles	0.77	1.88
Various plastic	1.11	4.05
PP bags, vessels, and packages	0.86	1.15
PE bags, vessels, and packages	28.73	24.39
Fabric	3.82	4.68
Tetrapack® packages	1.18	3.79
Glass	0.47	2.82
Organics	49.9	19.7
Other (e.g., lamps, batteries, electronics)	3.34	6.4
MSW's TOTAL COMPOSITION (%)	**100.00**	**100.00**

Source: Author's estimate based on SEMASA (SEMASA, 2008) and IPEA's data (IPEA, 2012)

Table B 2. Potential sorting of the MSW at MRSP

MRSP's MSW TOTAL (metric ton per day)	21,357.44	
	WTE	SORTING
	33%	67%
	7,153.29	14,204.15
	MATERIALS	
Aluminum	0.00	136.18
Rubber	19.48	62.53
Styrofoam	43.83	10.76
Natural wood	115.24	3.59
Processed wood	21.10	0.00
Metal	0.00	175.64
Paper	806.71	827.30
Cardboard	418.78	548.97
PET bottles	124.98	96.36
Various plastic	180.17	207.59
PP bags, vessels, and packages	139.59	58.95
PE bags, vessels and packages	4,663.35	1,250.18
Fabric	620.05	239.89
Tetrapack® packages	0.00	385.80
Glass	0.00	220.84
Organics	0.00	9,109.37
Other (e.g., lamps, batteries, electronics)	0.00	870.19

(*) Considered wet by WTE heating and aerobic process

Source: Author's potential estimate based on **Table B 1**.

Table B 3. Lower calorific values for wet components in the MSW

MATERIAL	Humidity (%)	LCV (kcal per kg)
Organic	66	712
Plastics	17	8,193
Paper or cardboard	21	2,729
Fabric or leather	36	1,921
Wood	25	2,490
Rubber	5	8,633

Source: The World Bank (HOORNWEG and BHADA-TATA, 2012), FEAM (FEAM, 2012) and NIXXON (NIXXON et al., 2013)

Table B 4. The energetic potential for the RDF

MSW's COMPONENT	FRACTION 33% 7,153.29		
	metric ton per day	Composition (%)	LCV (kcal per kg)
Aluminum	0.00	0.00%	0.00
Rubber	19.48	0.27%	23.51
Styrofoam	43.83	0.61%	50.20
Natural wood	115.24	1.61%	40.12
Processed wood	21.10	0.29%	7.35
Metal	0.00	0.00%	0.00
Paper	806.71	11.28%	307.76
Cardboard	418.78	5.85%	159.76
PET bottles	124.98	1.75%	143.15
Various plastic	180.17	2.52%	206.36
PP bags, vessels and packages	139.59	1.95%	159.88
PE bags, vessels and packages	4,663.35	65.19%	5,341.16
Fabric	620.05	8.67%	166.51
Tetrapack® packages	0.00	0.00%	0.00
Glass	0.00	0.00%	0.00
Organics	0.00	0.00%	0.00
Other (lamps, batteries, electronics…)	0.00	0.00%	0.00
MRSP's MSW TOTAL	7,153.29	100.00%	6,605.75

Source: Author's potential estimate based on **Table B 2** and **Table B 3**

APPENDIX C. Proposed locations for MBT+WtE units at MRSP

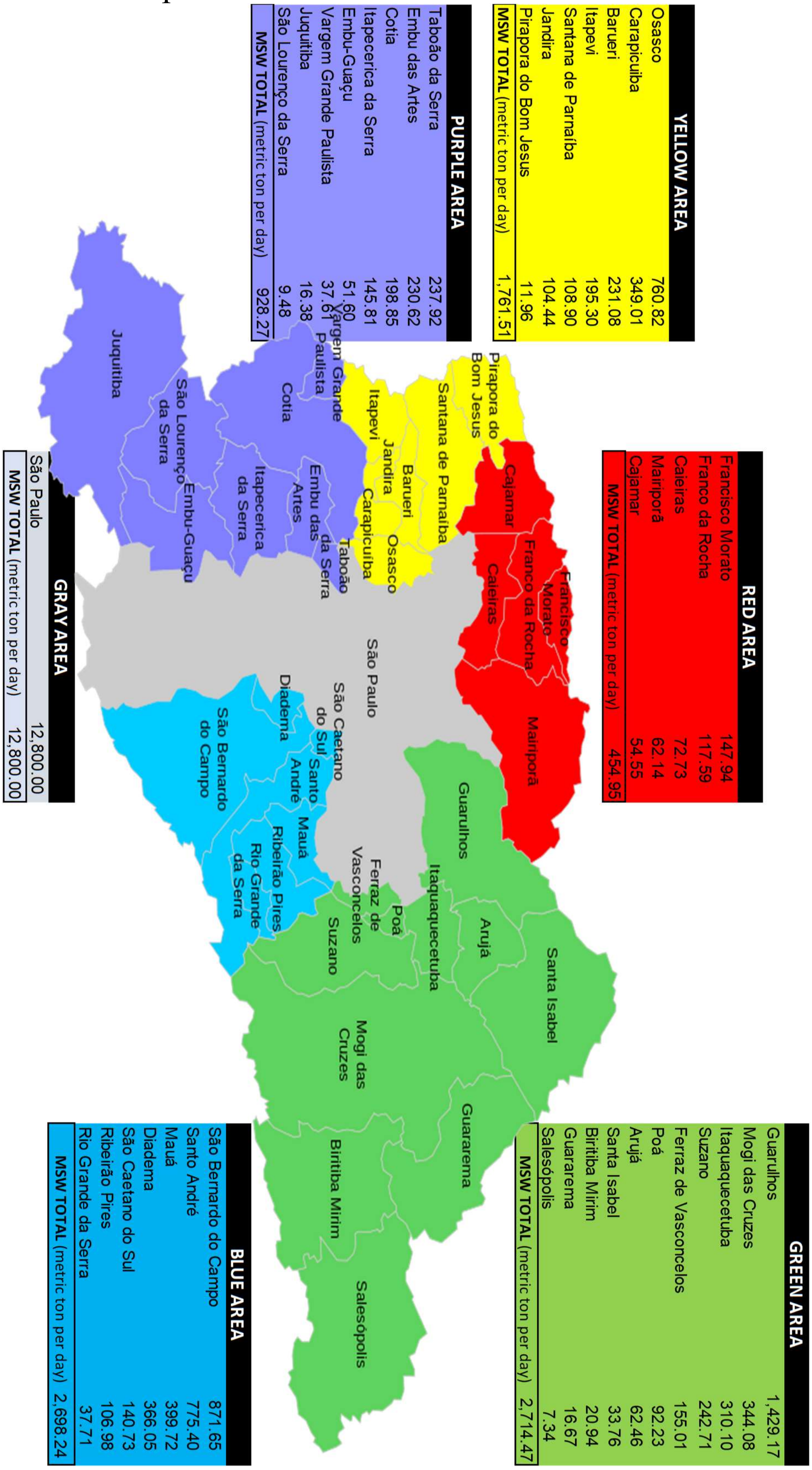

Figure C 1. Distribution of MSW at MRSP in 2013

Source: Author´s draft based on CETESB´s data (CETESB, 2014) – color

APPENDIX D. Human resources´ expenses

Table D 1. The breakdown of monthly expenses with HR

TYPE OF EXPENSE	REFERENCE	VALUE
Sorting salary	2014 national's minimum wage (R$ 724 or USD 309)	R$ 1,448.00 USD 618.80
Transport voucher	R$ 10 (USD 4.30) per day	R$ 220.00 USD 94.02
Transport voucher discount	6% of the employee's salary	-R$ 86.88 -USD 37.13
Meal voucher	R$ 15 (USD 6.41) per day	R$ 330.00 USD 141.03
Healthcare	Market offer	R$ 150.00 USD 64.10
Another benefit	-	R$ 0.00 USD 0.00
13th salary provisioning	CLT (BRASIL, 1943)	R$ 120.67 USD 51.57
Vacation provisioning	CLT	R$ 120.67 USD 51.57
1/3 of vacation provisioning	CLT	R$ 40.22 USD 17.19
FGTS (Service fund)	CLT	R$ 115.84 USD 49.50
FGTS (13th salary plus vacation) provisioning	CLT	R$ 22.52 USD 9.62
INSS (Social security)	20.00%	R$ 289.60 USD 123.76
INSS (13th salary plus vacation) provisioning	CLT	R$ 56.31 USD 24.06
Employee cost	**R$ 2,826.95 USD 1,208.10**	
Factor (Employee cost/salary)	**1.95**	

Source: Author's compilations and calculations

APPENDIX E. Energy Content, Recyclability, and Market of the Waste

Table E 1. Lower calorific values for components in wet MSW

MATERIAL	**Humidity** (%)	**LCV** (kcal per kg)
Organic	66	712
Plastics	17	8,193
Paper or cardboard	21	2,729
Fabric or leather	36	1,921
Wood	25	2,490
Rubber	5	8,633

Source: CEMIG-FEAM (FEAM, 2012)

Table E 2. The energetic potential for the fraction destined to the heat treatment

MSW's COMPONENT	FRACTION		
	33%		
	7,153.29		
	metric ton per day	Composition (%)	LCV (kcal per kg)
Aluminum	0.00	0.00%	0.00
Rubber	19.48	0.27%	23.51
Styrofoam	43.83	0.61%	50.20
Natural wood	115.24	1.61%	40.12
Processed wood	21.10	0.29%	7.35
Metal	0.00	0.00%	0.00
Paper	806.71	11.28%	307.76
Cardboard	418.78	5.85%	159.76
PET bottles	124.98	1.75%	143.15
Various plastic	180.17	2.52%	206.36
PP bags, vessels and packages	139.59	1.95%	159.88
PE bags, vessels and packages	4,663.35	65.19%	5,341.16
Fabric	620.05	8.67%	166.51
Tetrapack® packages	0.00	0.00%	0.00
Glass	0.00	0.00%	0.00
Organics	0.00	0.00%	0.00
Other (lamps, batteries, electronics…)	0.00	0.00%	0.00
MRSP's MSW TOTAL	7,153.29	100.00%	6,605.75

Source: Author's potential estimated based on SEMASA's data (SEMASA, 2008)

Table E 3. Techno-Economic Factors to use recyclables (based on 2009's prices)

PRODUCT	Value for Recyclables	Value for "Virgin"	% of Recyclable	% of "Virgin"	r Factor
Waste Treatment (R$/t)[a]	80	80	100	-	1.00
Aluminum (R$/t)[b]	2,800	3,279	100	-	0.85
Glass (R$/t)[c]	180	220	100	-	0.82
Paper (R$/t)[d]	510	2,737	50	50	0.19
Plastic (R$/t)[e]	1,700	3,400	60	40	0.75
Organic Compost (R$/t)[f]	125	725	80	20	0.69
Eletricity (R$/MWh)[g]	197	233	100	-	0.85

Source: Author's compilation based on following references:
a) ABRELPE (ABRELPE, 2016); b) ABAL (ABAL, 2016); c) ABIVIDRO (ABIVIDRO et al., 2016); d) ABTCP (ABTCP, 2016); e) CEMPRE (CEMPRE, 2013); f) AGROLINK (AGROLINK, 2016) e g) ANEEL (ANEEL, 2013)

APPENDIX F. Regional Direct and Indirect Effects

Table F 1. Direct and Indirect effects

2013's SECTORS OF THE ECONOMY	Metropolitan Region of São Paulo (MRSP)		Rest of São Paulo State		Rest of Brazil		Rest of Brazil	
	Direct Effect	Indirect Effect	Direct Effect	Indirect Effect	Direct Effect	Indirect Effect	Direct Effect	Indirect Effect
(S0) MBT+WtE	**100.0%**	**0.0%**	-	-	-	-	**100.0%**	**0.0%**
(S1) Agriculture, Forestry and Forestry	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S2) Livestock	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S3) Oil & Gas	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S4) Iron ore	0.3%	99.7%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S5) Other from Extractive Industry	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S6) Food and Beverage	0.0%	100.0%	0.2%	99.8%	0.0%	100.0%	0.0%	100.0%
(S7) Products from Smoke (Tobacco)	0.3%	99.7%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S8) Textiles	0.0%	100.0%	0.0%	100.0%	0.6%	99.4%	0.0%	100.0%
(S9) Articles and accessories of Clothing	2.2%	97.8%	1.0%	99.0%	0.0%	100.0%	0.0%	100.0%
(S10) Leather Goods and Footwear	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S11) Wood Products - except Furniture	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S12) Cellulose and Paper Products	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S13) Newspapers, Magazines and Discs	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S14) Petroleum Refining and Coke	0.7%	99.3%	0.5%	99.5%	0.1%	99.9%	0.0%	100.0%
(S15) Alcohol	0.4%	99.6%	0.5%	99.5%	0.0%	100.0%	0.0%	100.0%
(S16) Chemical Products	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S17) Resins and Elastomers Production	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S18) Pharmaceutic Products	0.2%	99.8%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S19) Agricultural Defensive Agents	0.0%	100.0%	0.0%	100.0%	0.1%	99.9%	0.0%	100.0%
(S20) Perfumery, Health and Cleaning	1.9%	98.1%	0.8%	99.2%	0.0%	100.0%	0.0%	100.0%
(S21) Paints, Varnishes and Lacquers	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S22) Products from various Chemicals	0.0%	100.0%	0.0%	100.0%	0.1%	99.9%	0.0%	100.0%
(S23) Rubber and Plastic Articles	1.3%	98.7%	0.3%	99.7%	0.0%	100.0%	0.0%	100.0%
(S24) Cement	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S25) Other Products from Non-Metallic Minerals	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S26) Steel Production and Derivatives	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S27) Metallurgy of Non-Ferrous Metals	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S28) Metal Products - except Machines and Appliances	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S29) Machines and Appliances - including Maintenance and Repairs	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S30) Household Appliances	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S31) Office Machines and Computing Devices	0.0%	100.0%	0.0%	100.0%	0.1%	99.9%	0.0%	100.0%
(S32) Machines, Devices and Electric Materials	1.2%	98.8%	0.4%	99.6%	0.0%	100.0%	0.0%	100.0%
(S33) Electronic Materials and Communication Appliances	0.9%	99.1%	0.2%	99.8%	0.0%	100.0%	0.0%	100.0%
(S34) Devices, Medical instruments	0.0%	100.0%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S35) Passenger cars and utilities	0.0%	100.0%	1.9%	98.1%	0.0%	100.0%	0.0%	100.0%
(S36) Trucks and Buses	0.0%	100.0%	0.0%	100.0%	0.1%	99.9%	0.0%	100.0%
(S37) Parts and accessories for automobiles	6.0%	94.0%	1.3%	98.7%	0.0%	100.0%	0.0%	100.0%
(S38) Other Appliances for Transport	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S39) Furniture and Other Products from diverse Industries	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S40) Electricity, Gas, Water, Sewage and Urban Cleaning	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S41) Building	0.8%	99.2%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S42) Commerce	1.8%	98.2%	0.1%	99.9%	0.1%	99.9%	0.0%	100.0%
(S43) Transport, Storage and Mail	0.6%	99.4%	0.2%	99.8%	0.0%	100.0%	0.0%	100.0%
(S44) Information Services	0.3%	99.7%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S45) Financial Intermediation and Insurance	0.2%	99.8%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S46) Estate Services and Rent	0.3%	99.7%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S47) Maintenance and Repair Services	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S48) Housing and Food Services	0.6%	99.4%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S49) Services for Companies	0.9%	99.1%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S50) Commercial Education	0.2%	99.8%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S51) Commercial Health	0.4%	99.6%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S52) Services for Families and Associative	1.7%	98.3%	0.3%	99.7%	0.0%	0.0%	0.0%	100.0%
(S53) Domestic Services	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S54) Public Education	1.5%	98.5%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S55) Public Health	0.9%	99.1%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S56) Public Administration and Social Security	2.0%	98.0%	0.1%	99.9%	0.0%	100.0%	0.0%	100.0%
(S57) Non-Metallic Minerals Extraction	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S58) Production of Paper, Cardboard and their Products	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S59) Production of Glass and their Products	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S60) Aluminum Metallurgy	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S61) Electricity Production (Oil based)	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
(S62) Urban Cleaning Services	2.8%	97.2%	0.0%	100.0%	0.2%	99.8%	0.1%	99.9%
TOTAL	**1.0%**	**99.0%**	**0.1%**	**99.9%**	**0.0%**	**100.0%**	**0.2%**	**99.8%**

APPENDIX G. Impacts over GDP

Table G 1. Gross Domestic Product (GDP)

2013's SECTORS OF THE ECONOMY	Metropolitan Region of Sao Paulo (MRSP) Δ GDP				Rest of Sao Paulo state Δ GDP				Rest of Brazil Δ GDP				BRAZIL Δ GDP			
	R$ million	USD million	Sector relevance	Economy relevance	R$ million	USD million	Sector relevance	Economy relevance	R$ million	USD million	Sector relevance	Economy relevance	R$ million	USD million	Sector relevance	Economy relevance
(S0) MBT+WtE	**3,210**	**1,372**	**100.0%**	**169.1%**	-	-	-	-	-	-	-		**3,210**	**1,372**	**100.0%**	**-88.5%**
(S62) Urban Cleaning Services	-493.28	-210.81	-49.8%	-26.0%	-0.46	-0.20	-0.1%	0.0%	-3.59	-1.54	-0.1%	0.1%	-497.34	-212.54	-8.2%	13.7%
(S58) Production of Paper, Cardboard and their Products	-265.39	-113.42	-5.2%	-14.0%	-280.33	-119.80	-4.6%	29.0%	-563.40	-240.77	-6.1%	12.3%	-1,109.12	-473.98	-5.4%	30.6%
(S45) Financial Intermediation and Insurance	-147.86	-63.19	-0.1%	-7.8%	-49.91	-21.33	-0.1%	5.2%	-213.86	-91.39	-0.1%	4.7%	-411.63	-175.91	-0.1%	11.3%
(S17) Resins and Elastomers Production	-95.11	-40.65	-5.8%	-5.0%	-59.36	-25.37	-6.1%	6.1%	-230.89	-98.67	-6.1%	5.1%	-385.36	-164.68	-6.0%	10.6%
(S43) Transport, Storage and Mail	-80.16	-34.26	-0.2%	-4.2%	-64.02	-27.36	-0.2%	6.6%	-311.76	-133.23	-0.2%	6.8%	-455.94	-194.85	-0.2%	12.6%
(S49) Services for Companies	-74.31	-31.76	-0.1%	-3.9%	-34.77	-14.86	-0.1%	3.6%	-163.45	-69.85	-0.1%	3.6%	-272.54	-116.47	-0.1%	7.5%
(S44) Information Services	-51.12	-21.85	-0.1%	-2.7%	-13.08	-5.59	-0.1%	1.4%	-77.40	-33.08	-0.1%	1.7%	-141.60	-60.51	-0.1%	3.9%
(S61) Electricity Production (Oil based)	-47.33	-20.23	-256.8%	-2.5%	-23.96	-10.24	-256.8%	2.5%	-396.36	-169.38	-259.0%	8.7%	-467.65	-199.85	-258.6%	12.9%
(S23) Rubber and Plastic Articles	-39.49	-16.88	-0.4%	-2.1%	-17.16	-7.33	-0.2%	1.8%	-37.29	-15.94	-0.2%	0.8%	-93.94	-40.15	-0.3%	2.6%
(S14) Petroleum Refining and Coke	-34.65	-14.81	-0.8%	-1.8%	-83.78	-35.81	-0.6%	8.7%	-234.47	-100.20	-0.5%	5.1%	-352.90	-150.81	-0.6%	9.7%
(S16) Chemical Products	-30.28	-12.94	-0.9%	-1.6%	-39.83	-17.02	-0.8%	4.1%	-217.54	-92.97	-1.3%	4.8%	-287.65	-122.93	-1.1%	7.9%
(S42) Commerce	-25.76	-11.01	0.0%	-1.4%	-56.82	-24.28	-0.1%	5.9%	-361.33	-154.42	-0.1%	7.9%	-443.91	-189.71	-0.1%	12.2%
(S46) Estate Services and Rent	-22.78	-9.74	0.0%	-1.2%	-11.37	-4.86	0.0%	1.2%	-75.72	-32.36	0.0%	1.7%	-109.87	-46.95	0.0%	3.0%
(S28) Metal Products - except Machines and Equipments	-22.48	-9.61	-0.2%	-1.2%	-20.63	-8.82	-0.2%	2.1%	-37.17	-15.89	-0.2%	0.8%	-80.29	-34.31	-0.2%	2.2%
(S22) Products from various Chemicals	-21.75	-9.29	-0.8%	-1.1%	-17.29	-7.39	-0.8%	1.8%	-24.43	-10.44	-0.9%	0.5%	-63.47	-27.12	-0.8%	1.7%
(S32) Machines, Devices and Electric Materials	-15.58	-6.66	-0.2%	-0.8%	-10.23	-4.37	-0.2%	1.1%	-15.17	-6.48	-0.1%	0.3%	-40.97	-17.51	-0.2%	1.1%
(S56) Public Administration and Social Security	-14.03	-6.00	0.0%	-0.7%	-3.73	-1.59	0.0%	0.4%	-39.03	-16.68	0.0%	0.9%	-56.79	-24.27	0.0%	1.6%
(S13) Newspapers, Magazines and Discs	-12.46	-5.33	-0.1%	-0.7%	-4.31	-1.84	-0.1%	0.4%	-20.32	-8.68	-0.1%	0.4%	-37.09	-15.85	-0.1%	1.0%
(S52) Services for Families and Associatives	-12.38	-5.29	-0.1%	-0.7%	-3.32	-1.42	0.0%	0.3%	-21.03	-8.99	0.0%	0.5%	-36.73	-15.70	0.0%	1.0%
(S29) Machines and Equipments - including Maintanance and Repairs	-11.85	-5.06	-0.1%	-0.6%	-15.99	-6.83	-0.1%	1.7%	-20.68	-8.84	-0.1%	0.5%	-48.52	-20.74	-0.1%	1.3%
(S21) Paints, Varnishes and Lacquers	-9.79	-4.18	-0.3%	-0.5%	-3.85	-1.64	-0.3%	0.4%	-11.33	-4.84	-0.4%	0.2%	-24.96	-10.67	-0.3%	0.7%
(S20) Perfumery, Health and Cleaning	-9.41	-4.02	-0.2%	-0.5%	-3.09	-1.32	-0.1%	0.3%	-27.99	-11.96	-0.4%	0.6%	-40.48	-17.30	-0.3%	1.1%
(S19) Agricultural Defensive Agents	-6.05	-2.58	-0.3%	-0.3%	-5.82	-2.49	-0.3%	0.6%	-11.58	-4.95	-0.5%	0.3%	-23.44	-10.02	-0.4%	0.6%
(S57) Non-Metallic Minerals Extraction	-4.97	-2.12	-3.0%	-0.3%	-11.46	-4.90	-3.0%	1.2%	-287.85	-123.01	-4.6%	6.3%	-304.28	-130.03	-4.5%	8.4%
(S8) Textiles	-4.73	-2.02	-0.1%	-0.2%	-8.23	-3.52	-0.1%	0.9%	-19.39	-8.29	-0.1%	0.4%	-32.35	-13.82	-0.1%	0.9%
(S26) Steel Production and Derivatives	-4.65	-1.99	-0.1%	-0.2%	-4.72	-2.02	-0.1%	0.5%	-50.88	-21.74	-0.2%	1.1%	-60.25	-25.75	-0.2%	1.7%
(S41) Building	-4.45	-1.90	0.0%	-0.2%	-2.34	-1.00	0.0%	0.2%	-14.37	-6.14	0.0%	0.3%	-21.16	-9.04	0.0%	0.6%
(S5) Other from Extractive Industry	-4.04	-1.72	-12.3%	-0.2%	-1.04	-0.44	-10.5%	0.1%	-258.46	-110.45	-4.7%	5.7%	-263.53	-112.62	-4.8%	7.3%
(S48) Housing and Food Services	-3.19	-1.36	0.0%	-0.2%	-2.05	-0.88	0.0%	0.2%	-9.07	-3.88	0.0%	0.2%	-14.30	-6.11	0.0%	0.4%
(S18) Pharmaceutic Products	-2.81	-1.20	0.0%	-0.1%	-1.00	-0.43	0.0%	0.1%	-3.90	-1.67	0.0%	0.1%	-7.71	-3.30	0.0%	0.2%
(S12) Cellulose and Paper Products	-2.54	-1.09	-0.5%	-0.1%	-2.97	-1.27	-0.6%	0.3%	-21.65	-9.25	-0.7%	0.5%	-27.16	-11.61	-0.6%	0.7%
(S27) Metallurgy of Non-Ferrous Metals	-2.44	-1.04	-0.1%	-0.1%	-1.28	-0.55	-0.1%	0.1%	-5.21	-2.22	-0.1%	0.1%	-8.93	-3.82	-0.1%	0.2%
(S9) Articles and accessories of Clothing	-2.26	-0.96	0.0%	-0.1%	-0.60	-0.26	0.0%	0.1%	-1.68	-0.72	0.0%	0.0%	-4.53	-1.94	0.0%	0.1%
(S37) Parts and accessories for automotives	-2.26	-0.96	0.0%	-0.1%	-4.66	-1.99	0.0%	0.5%	-10.08	-4.31	-0.1%	0.2%	-17.00	-7.26	-0.1%	0.5%
(S60) Aluminum Metallurgy	-1.57	-0.67	-0.2%	-0.1%	-2.67	-1.14	-0.1%	0.3%	-4.29	-1.83	-0.1%	0.1%	-8.52	-3.64	-0.1%	0.2%
(S6) Food and Beverage	-1.18	-0.50	0.0%	-0.1%	-5.83	-2.49	0.0%	0.6%	-10.88	-4.65	0.0%	0.2%	-17.89	-7.64	0.0%	0.5%
(S39) Furnitures and Other Products from diverse Industries	-1.15	-0.49	0.0%	-0.1%	-1.90	-0.81	0.0%	0.2%	-5.08	-2.17	0.0%	0.1%	-8.13	-3.47	0.0%	0.2%
(S3) Oil & Gas	-1.11	-0.48	-0.2%	-0.1%	-2.11	-0.90	-0.2%	0.2%	-199.03	-85.06	-0.4%	4.4%	-202.26	-86.43	-0.4%	5.6%
(S51) Commercial Health	-0.93	-0.40	0.0%	0.0%	-0.71	-0.30	0.0%	0.1%	-4.05	-1.73	0.0%	0.1%	-5.69	-2.43	0.0%	0.2%
(S25) Other Products from Non-Metallic Minerals	-0.88	-0.38	-0.1%	0.0%	-2.67	-1.14	-0.1%	0.3%	-15.43	-6.59	-0.1%	0.3%	-18.97	-8.11	-0.1%	0.5%
(S59) Production of Glass and their Products	-0.71	-0.31	0.0%	0.0%	-0.34	-0.14	0.0%	0.0%	-0.45	-0.19	0.0%	0.0%	-1.50	-0.64	0.0%	0.0%
(S50) Commercial Education	-0.66	-0.28	0.0%	0.0%	-0.59	-0.25	0.0%	0.1%	-2.66	-1.14	0.0%	0.1%	-3.92	-1.67	0.0%	0.1%
(S1) Agriculture, Silviculture and Forestry	-0.59	-0.25	-0.3%	0.0%	-24.82	-10.61	-0.1%	2.6%	-217.76	-93.06	-0.1%	4.8%	-243.18	-103.92	-0.1%	6.7%
(S11) Wood Products - except Furnitures	-0.42	-0.18	-0.1%	0.0%	-1.21	-0.52	-0.1%	0.1%	-6.83	-2.92	-0.1%	0.1%	-8.46	-3.62	-0.1%	0.2%
(S36) Trucks and Buses	-0.38	-0.16	0.0%	0.0%	-0.02	-0.01	0.0%	0.0%	-0.11	-0.05	0.0%	0.0%	-0.51	-0.22	0.0%	0.0%
(S31) Office Machines and Computing Devices	-0.33	-0.14	0.0%	0.0%	-0.82	-0.35	0.0%	0.1%	-0.63	-0.27	0.0%	0.0%	-1.78	-0.76	0.0%	0.0%
(S33) Electronic Materials and Communication Equipments	-0.31	-0.13	0.0%	0.0%	-0.71	-0.30	0.0%	0.1%	-1.65	-0.70	0.0%	0.0%	-2.67	-1.14	0.0%	0.1%
(S15) Alcohol	-0.18	-0.08	-0.2%	0.0%	-16.56	-7.08	-0.2%	1.7%	-9.64	-4.12	-0.2%	0.2%	-26.38	-11.27	-0.2%	0.7%
(S54) Public Education	-0.15	-0.07	0.0%	0.0%	-0.14	-0.06	0.0%	0.0%	-0.46	-0.20	0.0%	0.0%	-0.75	-0.32	0.0%	0.0%
(S24) Cement	-0.12	-0.05	0.0%	0.0%	-0.37	-0.16	0.0%	0.0%	-2.32	-0.99	0.0%	0.1%	-2.82	-1.21	0.0%	0.1%
(S38) Other Equipments for Transport	-0.12	-0.05	0.0%	0.0%	-0.42	-0.18	0.0%	0.0%	-1.26	-0.54	0.0%	0.0%	-1.81	-0.77	0.0%	0.0%
(S10) Leather Goods and Footwear	-0.02	-0.01	0.0%	0.0%	-0.15	-0.06	0.0%	0.0%	-0.71	-0.30	0.0%	0.0%	-0.88	-0.38	0.0%	0.0%
(S2) Livestock	-0.01	0.00	0.0%	0.0%	-0.85	-0.36	0.0%	0.1%	-12.12	-5.18	0.0%	0.3%	-12.98	-5.55	0.0%	0.4%
(S4) Iron ore	-0.01	0.00	-0.1%	0.0%	0.00	0.00	0.0%	0.0%	-15.17	-6.48	-0.1%	0.3%	-15.18	-6.49	-0.1%	0.4%
(S55) Public Health	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	-0.01	0.00	0.0%	0.0%
(S7) Products from Smoke (Tobacco)	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%
(S53) Domestic Services	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%
(S34) Devices, Medical instruments	0.04	0.02	0.0%	0.0%	-0.53	-0.23	0.0%	0.1%	-0.88	-0.38	0.0%	0.0%	-1.37	-0.58	0.0%	0.0%
(S35) Passenger cars and utilities	0.35	0.15	0.0%	0.0%	-0.01	0.00	0.0%	0.0%	-0.09	-0.04	0.0%	0.0%	0.26	0.11	0.0%	0.0%
(S30) Household Appliances	0.39	0.17	0.0%	0.0%	0.20	0.08	0.0%	0.0%	-0.09	-0.04	0.0%	0.0%	0.50	0.22	0.0%	0.0%
(S40) Electricity, Gas, Water, Sewage and Urban Cleaning	18.14	7.75	0.1%	1.0%	-34.39	-14.70	-0.2%	3.6%	-236.45	-101.05	-0.2%	5.2%	-252.70	-107.99	-0.2%	7.0%
(S47) Maintanance and Repair Services	261.84	111.90	2.7%	13.8%	-4.55	-1.95	-0.1%	0.5%	-15.88	-6.78	-0.1%	0.3%	241.41	103.17	0.5%	-6.7%
TOTAL	**1,898.75**	**811.43**	**0.2%**	**100.0%**	**-965.63**	**-412.66**	**-0.2%**	**100.0%**	**-4,562.25**	**-1,949.68**	**-0.1%**	**100.0%**	**-3,629.13**	**-1,550.91**	**-0.1%**	**100.0%**

APPENDIX H. Impacts over Production Value

Table H 1. Production Value (X)

2013's SECTORS OF THE ECONOMY	Metropolitan Region of Sao Paulo (MRSP) Δ PRODUCTION VALUE (X)				Rest of Sao Paulo state Δ PRODUCTION VALUE (X)				Rest of Brazil Δ PRODUCTION VALUE (X)				BRAZIL Δ PRODUCTION VALUE (X)			
	R$ million	USD million	Sector relevance	Economy relevance	R$ million	USD million	Sector relevance	Economy relevance	R$ million	USD million	Sector relevance	Economy relevance	R$ million	USD million	Sector relevance	Economy relevance
(S0) MBT+WtE	**3,594**	**1,536**	**100.0%**	**-9215.6%**	-	-	-	-	-	-	-		**3,594**	**1,536**	**100.0%**	**-23.4%**
(S62) Urban Cleaning Services	-1,021.15	-436.39	-49.8%	2618.4%	-0.95	-0.41	-0.1%	0.0%	-7.50	-3.21	-0.1%	0.1%	-1,029.60	-440.00	-8.1%	6.7%
(S58) Production of Paper, Cardboard and their Products	-785.51	-335.69	-5.2%	2014.2%	-829.70	-354.57	-4.6%	29.6%	-1,720.56	-735.28	-6.1%	13.8%	-3,335.77	-1,425.54	-5.5%	21.7%
(S17) Resins and Elastomers Production	-517.94	-221.34	-5.8%	1328.1%	-323.24	-138.14	-6.1%	11.5%	-1,318.76	-563.57	-6.1%	10.5%	-2,159.93	-923.05	-6.0%	14.1%
(S45) Financial Intermediation and Insurance	-235.89	-100.81	-0.1%	604.9%	-79.63	-34.03	-0.1%	2.8%	-342.72	-146.46	-0.1%	2.7%	-658.24	-281.30	-0.1%	4.3%
(S61) Electricity Production (Oil based)	-162.43	-69.41	-256.8%	416.5%	-82.25	-35.15	-256.8%	2.9%	-1,454.45	-621.56	-259.0%	11.6%	-1,699.13	-726.12	-258.6%	11.1%
(S43) Transport, Storage and Mail	-154.81	-66.16	-0.2%	397.0%	-123.64	-52.84	-0.2%	4.4%	-640.15	-273.57	-0.2%	5.1%	-918.60	-392.57	-0.2%	6.0%
(S14) Petroleum Refining and Coke	-143.96	-61.52	-0.8%	369.1%	-348.12	-148.77	-0.6%	12.4%	-948.10	-405.17	-0.5%	7.6%	-1,440.17	-615.46	-0.6%	9.4%
(S49) Services for Companies	-134.44	-57.45	-0.1%	344.7%	-62.90	-26.88	-0.1%	2.2%	-262.18	-112.04	-0.1%	2.1%	-459.52	-196.38	-0.1%	3.0%
(S16) Chemical Products	-125.71	-53.72	-0.9%	322.3%	-165.37	-70.67	-0.8%	5.9%	-918.34	-392.45	-1.3%	7.3%	-1,209.42	-516.85	-1.1%	7.9%
(S23) Rubber and Plastic Articles	-117.51	-50.22	-0.4%	301.3%	-51.07	-21.83	-0.2%	1.8%	-110.38	-47.17	-0.2%	0.9%	-278.96	-119.22	-0.3%	1.8%
(S44) Information Services	-103.70	-44.32	-0.1%	265.9%	-26.54	-11.34	-0.1%	0.9%	-158.68	-67.81	-0.1%	1.3%	-288.92	-123.47	-0.1%	1.9%
(S22) Products from various Chemicals	-70.94	-30.32	-0.8%	181.9%	-56.40	-24.10	-0.8%	2.0%	-79.23	-33.86	-0.9%	0.6%	-206.57	-88.28	-0.8%	1.3%
(S28) Metal Products - except Machines and Appliances	-51.54	-22.03	-0.2%	132.2%	-47.29	-20.21	-0.2%	1.7%	-83.84	-35.83	-0.2%	0.7%	-182.68	-78.07	-0.2%	1.2%
(S32) Machines, Devices and Electric Materials	-46.09	-19.70	-0.2%	118.2%	-30.26	-12.93	-0.2%	1.1%	-45.15	-19.29	-0.1%	0.4%	-121.50	-51.92	-0.2%	0.8%
(S42) Commerce	-39.59	-16.92	0.0%	101.5%	-87.34	-37.33	-0.1%	3.1%	-529.36	-226.22	-0.1%	4.2%	-656.29	-280.47	-0.1%	4.3%
(S29) Machines and Appliances - including Maintanance and Repairs	-34.82	-14.88	-0.1%	89.3%	-46.97	-20.07	-0.1%	1.7%	-61.30	-26.20	-0.1%	0.5%	-143.09	-61.15	-0.1%	0.9%
(S20) Perfumery, Health and Cleaning	-27.85	-11.90	-0.2%	71.4%	-9.14	-3.90	-0.1%	0.3%	-80.86	-34.56	-0.4%	0.6%	-117.85	-50.36	-0.3%	0.8%
(S46) Estate Services and Rent	-27.11	-11.59	0.0%	69.5%	-13.54	-5.78	0.0%	0.5%	-88.25	-37.71	0.0%	0.7%	-128.90	-55.08	0.0%	0.8%
(S19) Agricultural Defensive Agents	-26.89	-11.49	-0.3%	68.9%	-25.87	-11.06	-0.3%	0.9%	-53.81	-22.99	-0.5%	0.4%	-106.56	-45.54	-0.4%	0.7%
(S21) Paints, Varnishes and Lacquers	-25.77	-11.01	-0.3%	66.1%	-10.13	-4.33	-0.3%	0.4%	-29.24	-12.50	-0.4%	0.2%	-65.14	-27.84	-0.3%	0.4%
(S13) Newspapers, Magazines and Discs	-25.04	-10.70	-0.1%	64.2%	-8.65	-3.70	-0.1%	0.3%	-39.37	-16.82	-0.1%	0.3%	-73.07	-31.22	-0.1%	0.5%
(S52) Services for Families and Associative	-24.03	-10.27	-0.1%	61.6%	-6.44	-2.75	0.0%	0.2%	-39.79	-17.01	0.0%	0.3%	-70.27	-30.03	0.0%	0.5%
(S56) Public Administration and Social Security	-22.88	-9.78	0.0%	58.7%	-6.08	-2.60	0.0%	0.2%	-62.10	-26.54	0.0%	0.5%	-91.07	-38.92	0.0%	0.6%
(S57) Non-Metallic Minerals Extraction	-15.65	-6.69	-3.0%	40.1%	-36.12	-15.44	-3.0%	1.3%	-884.92	-378.17	-4.6%	7.1%	-936.70	-400.30	-4.5%	6.1%
(S26) Steel Production and Derivatives	-14.19	-6.06	-0.1%	36.4%	-14.42	-6.16	-0.1%	0.5%	-149.33	-63.82	-0.2%	1.2%	-177.94	-76.04	-0.2%	1.2%
(S8) Textiles	-12.43	-5.31	-0.1%	31.9%	-21.63	-9.25	-0.1%	0.8%	-50.00	-21.37	-0.1%	0.4%	-84.07	-35.93	-0.1%	0.5%
(S41) Building	-8.86	-3.79	0.0%	22.7%	-4.66	-1.99	0.0%	0.2%	-28.14	-12.02	0.0%	0.2%	-41.66	-17.80	0.0%	0.3%
(S27) Metallurgy of Non-Ferrous Metals	-8.48	-3.62	-0.1%	21.7%	-4.45	-1.90	-0.1%	0.2%	-18.29	-7.81	-0.1%	0.1%	-31.22	-13.34	-0.1%	0.2%
(S12) Cellulose and Paper Products	-8.33	-3.56	-0.5%	21.4%	-9.71	-4.15	-0.6%	0.3%	-68.49	-29.27	-0.7%	0.5%	-86.53	-36.98	-0.6%	0.6%
(S5) Others from Extractive Industry	-7.73	-3.30	-12.3%	19.8%	-1.99	-0.85	-10.5%	0.1%	-536.35	-229.21	-4.7%	4.3%	-546.08	-233.37	-4.8%	3.6%
(S48) Housing and Food Services	-7.31	-3.12	0.0%	18.7%	-4.70	-2.01	0.0%	0.2%	-18.00	-7.69	0.0%	0.1%	-30.00	-12.82	0.0%	0.2%
(S37) Parts and accessories for automobiles	-7.25	-3.10	0.0%	18.6%	-14.95	-6.39	0.0%	0.5%	-32.72	-13.98	-0.1%	0.3%	-54.91	-23.47	-0.1%	0.4%
(S18) Pharmaceutic Products	-5.96	-2.55	0.0%	15.3%	-2.13	-0.91	0.0%	0.1%	-7.68	-3.28	0.0%	0.1%	-15.77	-6.74	0.0%	0.1%
(S60) Aluminum Metallurgy	-5.39	-2.31	-0.2%	13.8%	-9.16	-3.92	-0.1%	0.3%	-15.22	-6.50	-0.1%	0.1%	-29.78	-12.72	-0.1%	0.2%
(S9) Articles and accessories of Clothing	-5.31	-2.27	0.0%	13.6%	-1.40	-0.60	0.0%	0.1%	-3.81	-1.63	0.0%	0.0%	-10.52	-4.50	0.0%	0.1%
(S6) Food and Beverage	-4.99	-2.13	0.0%	12.8%	-24.59	-10.51	0.0%	0.9%	-52.34	-22.37	0.0%	0.4%	-81.91	-35.01	0.0%	0.5%
(S3) Oil & Gas	-2.95	-1.26	-0.2%	7.6%	-5.60	-2.39	-0.2%	0.2%	-539.37	-230.50	-0.4%	4.3%	-547.92	-234.15	-0.4%	3.6%
(S39) Furnitures and Other Products from diverse Industries	-2.62	-1.12	0.0%	6.7%	-4.31	-1.84	0.0%	0.2%	-11.64	-4.98	0.0%	0.1%	-18.57	-7.93	0.0%	0.1%
(S25) Other Products from Non-Metallic Minerals	-2.30	-0.98	-0.1%	5.9%	-6.97	-2.98	-0.1%	0.2%	-39.16	-16.73	-0.1%	0.3%	-48.43	-20.70	-0.1%	0.3%
(S36) Trucks and Buses	-1.87	-0.80	0.0%	4.8%	-0.11	-0.05	0.0%	0.0%	-0.60	-0.26	0.0%	0.0%	-2.58	-1.10	0.0%	0.0%
(S51) Commercial Health	-1.71	-0.73	0.0%	4.4%	-1.31	-0.56	0.0%	0.0%	-7.38	-3.15	0.0%	0.1%	-10.40	-4.45	0.0%	0.1%
(S59) Production of Glass and their Products	-1.59	-0.68	0.0%	4.1%	-0.75	-0.32	0.0%	0.0%	-0.96	-0.41	0.0%	0.0%	-3.30	-1.41	0.0%	0.0%
(S31) Office Machines and Computing Devices	-1.44	-0.61	0.0%	3.7%	-3.51	-1.50	0.0%	0.1%	-2.96	-1.27	0.0%	0.0%	-7.91	-3.38	0.0%	0.1%
(S1) Agriculture, Silviculture and Forestry	-1.28	-0.55	-0.3%	3.3%	-53.45	-22.84	-0.1%	1.9%	-363.85	-155.49	-0.1%	2.9%	-418.57	-178.88	-0.1%	2.7%
(S33) Electronic Materials and Communication Appliances	-1.23	-0.52	0.0%	3.1%	-2.80	-1.19	0.0%	0.1%	-7.45	-3.19	0.0%	0.1%	-11.48	-4.90	0.0%	0.1%
(S50) Commercial Education	-1.06	-0.45	0.0%	2.7%	-0.95	-0.41	0.0%	0.0%	-4.22	-1.81	0.0%	0.0%	-6.24	-2.66	0.0%	0.0%
(S11) Wood Products - except Furnitures	-0.99	-0.42	-0.1%	2.5%	-2.85	-1.22	-0.1%	0.1%	-16.30	-6.97	-0.1%	0.1%	-20.14	-8.61	-0.1%	0.1%
(S15) Alcohol	-0.52	-0.22	-0.2%	1.3%	-48.93	-20.91	-0.2%	1.7%	-30.09	-12.86	-0.2%	0.2%	-79.54	-33.99	-0.2%	0.5%
(S38) Other Appliances for Transport	-0.44	-0.19	0.0%	1.1%	-1.52	-0.65	0.0%	0.1%	-4.73	-2.02	0.0%	0.0%	-6.69	-2.86	0.0%	0.0%
(S24) Cement	-0.39	-0.17	0.0%	1.0%	-1.17	-0.50	0.0%	0.0%	-7.11	-3.04	0.0%	0.1%	-8.67	-3.71	0.0%	0.1%
(S54) Public Education	-0.22	-0.09	0.0%	0.6%	-0.20	-0.08	0.0%	0.0%	-0.63	-0.27	0.0%	0.0%	-1.05	-0.45	0.0%	0.0%
(S10) Leather Goods and Footwear	-0.05	-0.02	0.0%	0.1%	-0.41	-0.17	0.0%	0.0%	-1.90	-0.81	0.0%	0.0%	-2.36	-1.01	0.0%	0.0%
(S2) Livestock	-0.04	-0.02	0.0%	0.1%	-2.69	-1.15	0.0%	0.1%	-23.41	-10.01	0.0%	0.2%	-26.14	-11.17	0.0%	0.2%
(S4) Iron ore	-0.02	-0.01	-0.1%	0.0%	0.00	0.00	0.0%	0.0%	-30.91	-13.21	-0.1%	0.2%	-30.93	-13.22	-0.1%	0.2%
(S55) Public Health	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	-0.01	0.00	0.0%	0.0%	-0.01	0.00	0.0%	0.0%
(S7) Products from Smoke (Tobacco)	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%
(S53) Domestic Services	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%	0.00	0.00	0.0%	0.0%
(S34) Devices, Medical instruments	0.08	0.03	0.0%	-0.2%	-0.97	-0.41	0.0%	0.0%	-1.62	-0.69	0.0%	0.0%	-2.51	-1.07	0.0%	0.0%
(S30) Household Appliances	1.35	0.58	0.0%	-3.5%	0.67	0.29	0.0%	0.0%	-0.31	-0.13	0.0%	0.0%	1.71	0.73	0.0%	0.0%
(S35) Passenger cars and utilities	1.99	0.85	0.0%	-5.1%	-0.03	-0.01	0.0%	0.0%	-0.54	-0.23	0.0%	0.0%	1.42	0.61	0.0%	0.0%
(S40) Electricity, Gas, Water, Sewage and Urban Cleaning	35.02	14.97	0.1%	-89.8%	-66.40	-28.38	-0.2%	2.4%	-446.84	-190.96	-0.2%	3.6%	-478.22	-204.37	-0.2%	3.1%
(S47) Maintenance and Repair Services	386.77	165.29	2.7%	-991.7%	-6.73	-2.88	-0.1%	0.2%	-21.91	-9.37	-0.1%	0.2%	358.13	153.05	0.6%	-2.3%
TOTAL	**-39.00**	**-16.67**	**0.0%**	**100.0%**	**-2,802.46**	**-1,197.63**	**-0.2%**	**100.0%**	**-12,503.32**	**-5,343.30**	**-0.2%**	**100.0%**	**-15,344.77**	**-6,557.60**	**-0.2%**	**100.0%**

APPENDIX I. Impacts over Number of Jobs

Table I 1. Number of Jobs

2013's SECTORS OF THE ECONOMY	Metropolitan Region of Sao Paulo (MRSP) Δ JOB POSITIONS			Rest of Sao Paulo state Δ JOB POSITIONS			Rest of Brazil Δ JOB POSITIONS			BRAZIL Δ JOB POSITIONS		
	Qty	Sector relevance	Economy relevance	Qty	Sector relevance	Economy relevance	Qty	Sector relevance	Economy relevance	Qty	Sector relevance	Economy relevance
(S0) CENTRAL OF RECYCLING	**10,678**	**100.0%**	**101.1%**	-	-	-	-	-	-	**10,678**	**100.0%**	**222.1%**
(S58) Production of Paper, Cardboard and their Products	-164	-0.4%	-1.6%	-173	-0.3%	25.1%	-443	-0.4%	8.7%	-780	-0.4%	-16.2%
(S49) Services for Companies	-93	0.0%	-0.9%	-43	0.0%	6.3%	-350	0.0%	6.9%	-486	0.0%	-10.1%
(S43) Transport, Storage and Mail	-83	0.0%	-0.8%	-67	0.0%	9.6%	-456	0.0%	9.0%	-605	0.0%	-12.6%
(S42) Commerce	-40	0.0%	-0.4%	-89	0.0%	12.9%	-877	0.0%	17.3%	-1,007	0.0%	-20.9%
(S23) Rubber and Plastic Articles	-31	0.0%	-0.3%	-14	0.0%	2.0%	-41	0.0%	0.8%	-85	0.0%	-1.8%
(S44) Information Services	-30	0.0%	-0.3%	-8	0.0%	1.1%	-76	0.0%	1.5%	-114	0.0%	-2.4%
(S52) Services for Families and Associatives	-27	0.0%	-0.3%	-7	0.0%	1.0%	-77	0.0%	1.5%	-111	0.0%	-2.3%
(S45) Financial Intermediation and Insurance	-24	0.0%	-0.2%	-8	0.0%	1.2%	-60	0.0%	1.2%	-92	0.0%	-1.9%
(S17) Resins and Elastomers Production	-24	-0.4%	-0.2%	-15	-0.4%	2.2%	-80	-0.4%	1.6%	-119	-0.4%	-2.5%
(S28) Metal Products - except Machines and Equipments	-20	0.0%	-0.2%	-19	0.0%	2.7%	-56	0.0%	1.1%	-95	0.0%	-2.0%
(S57) Non-Metallic Minerals Extraction	-16	-0.2%	-0.2%	-37	-0.2%	5.3%	-463	-0.3%	9.2%	-516	-0.3%	-10.7%
(S22) Products from various Chemicals	-15	-0.1%	-0.1%	-12	-0.1%	1.7%	-24	-0.1%	0.5%	-51	-0.1%	-1.1%
(S56) Public Administration and Social Security	-11	0.0%	-0.1%	-3	0.0%	0.4%	-34	0.0%	0.7%	-48	0.0%	-1.0%
(S32) Machines, Devices and Electric Materials	-10	0.0%	-0.1%	-7	0.0%	1.0%	-13	0.0%	0.3%	-30	0.0%	-0.6%
(S29) Machines and Equipments - including Maintanance and Repairs	-9	0.0%	-0.1%	-13	0.0%	1.8%	-21	0.0%	0.4%	-43	0.0%	-0.9%
(S8) Textiles	-9	0.0%	-0.1%	-16	0.0%	2.2%	-63	0.0%	1.2%	-87	0.0%	-1.8%
(S13) Newspapers, Magazines and Discs	-9	0.0%	-0.1%	-3	0.0%	0.4%	-22	0.0%	0.4%	-33	0.0%	-0.7%
(S9) Articles and accessories of Clothing	-8	0.0%	-0.1%	-2	0.0%	0.3%	-9	0.0%	0.2%	-20	0.0%	-0.4%
(S16) Chemical Products	-8	-0.1%	-0.1%	-10	-0.1%	1.5%	-65	-0.1%	1.3%	-83	-0.1%	-1.7%
(S41) Building	-7	0.0%	-0.1%	-4	0.0%	0.6%	-33	0.0%	0.7%	-44	0.0%	-0.9%
(S48) Housing and Food Services	-6	0.0%	-0.1%	-4	0.0%	0.6%	-31	0.0%	0.6%	-41	0.0%	-0.9%
(S61) Electricity Production (Oil based)	-5	-18.0%	0.0%	-3	-18.0%	0.4%	-92	-18.1%	1.8%	-100	-19.2%	-2.1%
(S20) Perfumery, Health and Cleaning	-4	0.0%	0.0%	-1	0.0%	0.2%	-18	0.0%	0.4%	-24	0.0%	-0.5%
(S5) Others from Extractive Industry	-4	-0.9%	0.0%	-1	-0.7%	0.2%	-127	-0.3%	2.5%	-133	-0.4%	-2.8%
(S46) Estate Services and Rent	-3	0.0%	0.0%	-2	0.0%	0.2%	-10	0.0%	0.2%	-15	0.0%	-0.3%
(S21) Paints, Varnishes and Lacquers	-3	0.0%	0.0%	-1	0.0%	0.2%	-4	0.0%	0.1%	-9	0.0%	-0.2%
(S1) Agriculture, Silviculture and Forestry	-2	0.0%	0.0%	-81	0.0%	11.7%	-1,178	0.0%	23.3%	-1,261	0.0%	-26.2%
(S39) Furnitures and Other Products from diverse Industries	-2	0.0%	0.0%	-3	0.0%	0.4%	-12	0.0%	0.2%	-17	0.0%	-0.4%
(S19) Agricultural Defensive Agents	-2	0.0%	0.0%	-1	0.0%	0.2%	-4	0.0%	0.1%	-7	0.0%	-0.1%
(S37) Parts and accessories for automotives	-1	0.0%	0.0%	-3	0.0%	0.4%	-8	0.0%	0.2%	-13	0.0%	-0.3%
(S27) Metallurgy of Non-Ferrous Metals	-1	0.0%	0.0%	-1	0.0%	0.1%	-5	0.0%	0.1%	-7	0.0%	-0.1%
(S6) Food and Beverage	-1	0.0%	0.0%	-6	0.0%	0.9%	-17	0.0%	0.3%	-24	0.0%	-0.5%
(S25) Other Products from Non-Metallic Minerals	-1	0.0%	0.0%	-4	0.0%	0.5%	-35	0.0%	0.7%	-40	0.0%	-0.8%
(S50) Commercial Education	-1	0.0%	0.0%	-1	0.0%	0.1%	-7	0.0%	0.1%	-9	0.0%	-0.2%
(S51) Commercial Health	-1	0.0%	0.0%	-1	0.0%	0.1%	-8	0.0%	0.2%	-9	0.0%	-0.2%
(S26) Steel Production and Derivatives	-1	0.0%	0.0%	-1	0.0%	0.1%	-13	0.0%	0.3%	-14	0.0%	-0.3%
(S18) Pharmaceutic Products	-1	0.0%	0.0%	0	0.0%	0.0%	-1	0.0%	0.0%	-2	0.0%	0.0%
(S11) Wood Products - except Furnitures	-1	0.0%	0.0%	-2	0.0%	0.2%	-20	0.0%	0.4%	-22	0.0%	-0.5%
(S12) Cellulose and Paper Products	0	0.0%	0.0%	-1	0.0%	0.1%	-6	0.0%	0.1%	-7	0.0%	-0.1%
(S14) Petroleum Refining and Coke	0	-0.1%	0.0%	-1	0.0%	0.1%	-9	0.0%	0.2%	-10	0.0%	-0.2%
(S59) Production of Glass and their Products	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	-1	0.0%	0.0%
(S60) Aluminum Metallurgy	0	0.0%	0.0%	0	0.0%	0.1%	-2	0.0%	0.0%	-3	0.0%	-0.1%
(S54) Public Education	0	0.0%	0.0%	0	0.0%	0.0%	-1	0.0%	0.0%	-1	0.0%	0.0%
(S33) Electronic Materials and Communication Equipments	0	0.0%	0.0%	0	0.0%	0.1%	-1	0.0%	0.0%	-2	0.0%	0.0%
(S3) Oil & Gas	0	0.0%	0.0%	0	0.0%	0.0%	-19	0.0%	0.4%	-19	0.0%	-0.4%
(S31) Office Machines and Computing Devices	0	0.0%	0.0%	0	0.0%	0.1%	0	0.0%	0.0%	-1	0.0%	0.0%
(S36) Trucks and Buses	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S15) Alcohol	0	0.0%	0.0%	-7	0.0%	1.1%	-10	0.0%	0.2%	-17	0.0%	-0.4%
(S38) Other Equipments for Transport	0	0.0%	0.0%	0	0.0%	0.0%	-1	0.0%	0.0%	-1	0.0%	0.0%
(S10) Leather Goods and Footwear	0	0.0%	0.0%	0	0.0%	0.0%	-2	0.0%	0.0%	-3	0.0%	-0.1%
(S2) Livestock	0	0.0%	0.0%	-2	0.0%	0.4%	-56	0.0%	1.1%	-58	0.0%	-1.2%
(S24) Cement	0	0.0%	0.0%	0	0.0%	0.0%	-1	0.0%	0.0%	-1	0.0%	0.0%
(S4) Iron ore	0	0.0%	0.0%	0	0.0%	0.0%	-2	0.0%	0.0%	-2	0.0%	0.0%
(S55) Public Health	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S7) Products from Smoke (Tobacco)	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S62) Urban Cleaning Services	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S53) Domestic Services	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S34) Devices, Medical instruments	0	0.0%	0.0%	0	0.0%	0.1%	-1	0.0%	0.0%	-1	0.0%	0.0%
(S35) Passenger cars and utilities	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S30) Household Appliances	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%	0	0.0%	0.0%
(S40) Electricity, Gas, Water, Sewage and Urban Cleaning	2	0.0%	0.0%	-4	0.0%	0.5%	-35	0.0%	0.7%	-37	0.0%	-0.8%
(S47) Maintanance and Repair Services	562	0.2%	5.3%	-10	0.0%	1.4%	-62	0.0%	1.2%	490	0.0%	10.2%
TOTAL	**10,559**	**0.08%**	**100.0%**	**-691**	**-0.01%**	**100.0%**	**-5,061**	**-0.01%**	**100.0%**	**4,807**	**0.00%**	**100.0%**

APPENDIX J. Impacts over Energy Consumption

Table J 1. Energy Consumption

2013's SECTORS OF THE ECONOMY	Metropolitan Region of Sao Paulo (MRSP) Δ ENERGY CONSUMPTION			Rest of Sao Paulo state Δ ENERGY CONSUMPTION			Rest of Brazil Δ ENERGY CONSUMPTION			BRAZIL Δ ENERGY CONSUMPTION		
	10^3 toe	Sector relevance	Economy relevance	10^3 toe	Sector relevance	Economy relevance	10^3 toe	Sector relevance	Economy relevance	10^3 toe	Sector relevance	Economy relevance
(S0) MBT+WtE	-	-	-	-	-	-	-	-	-	**0.00**	**100.0%**	**0.0%**
(S58) Production of Paper, Cardboard and their Products	-49.08	-5.2%	45.3%	-51.84	-4.6%	47.0%	-104.19	-6.1%	22.4%	-205.11	-5.4%	30.0%
(S43) Transport, Storage and Mail	-29.83	-0.2%	27.6%	-23.83	-0.2%	21.6%	-116.03	-0.2%	24.9%	-169.69	-0.2%	24.8%
(S17) Resins and Elastomers Production	-4.96	-5.8%	4.6%	-3.10	-6.1%	2.8%	-12.05	-6.1%	2.6%	-20.11	-6.0%	2.9%
(S61) Electricity Production (Oil based)	-4.66	-256.8%	4.3%	-2.36	-256.8%	2.1%	-39.03	-259.0%	8.4%	-46.05	-258.6%	6.7%
(S14) Petroleum Refining and Coke	-3.41	-0.8%	3.2%	-8.25	-0.6%	7.5%	-23.09	-0.5%	5.0%	-34.75	-0.6%	5.1%
(S62) Urban Cleaning Services	-2.60	-49.8%	2.4%	0.00	-0.1%	0.0%	-0.02	-0.1%	0.0%	-2.62	-8.2%	0.4%
(S13) Newspapers, Magazines and Discs	-2.30	-0.1%	2.1%	-0.80	-0.1%	0.7%	-3.76	-0.1%	0.8%	-6.86	-0.1%	1.0%
(S26) Steel Production and Derivatives	-2.09	-0.1%	1.9%	-2.13	-0.1%	1.9%	-22.91	-0.2%	4.9%	-27.13	-0.2%	4.0%
(S23) Rubber and Plastic Articles	-2.06	-0.4%	1.9%	-0.90	-0.2%	0.8%	-1.95	-0.2%	0.4%	-4.90	-0.3%	0.7%
(S16) Chemical Products	-1.58	-0.9%	1.5%	-2.08	-0.8%	1.9%	-11.35	-1.3%	2.4%	-15.01	-1.1%	2.2%
(S22) Products from various Chemicals	-1.13	-0.8%	1.0%	-0.90	-0.8%	0.8%	-1.27	-0.9%	0.3%	-3.31	-0.8%	0.5%
(S27) Metallurgy of Non-Ferrous Metals	-1.10	-0.1%	1.0%	-0.58	-0.1%	0.5%	-2.35	-0.1%	0.5%	-4.03	-0.1%	0.6%
(S60) Aluminum Metallurgy	-0.71	-0.2%	0.7%	-1.20	-0.1%	1.1%	-1.94	-0.1%	0.4%	-3.85	-0.1%	0.6%
(S45) Financial Intermediation and Insurance	-0.57	-0.1%	0.5%	-0.19	-0.1%	0.2%	-0.83	-0.1%	0.2%	-1.59	-0.1%	0.2%
(S21) Paints, Varnishes and Lacquers	-0.51	-0.3%	0.5%	-0.20	-0.3%	0.2%	-0.59	-0.4%	0.1%	-1.30	-0.3%	0.2%
(S20) Perfumery, Health and Cleaning	-0.49	-0.2%	0.5%	-0.16	-0.1%	0.1%	-1.46	-0.4%	0.3%	-2.11	-0.3%	0.3%
(S12) Cellulose and Paper Products	-0.47	-0.5%	0.4%	-0.55	-0.6%	0.5%	-4.00	-0.7%	0.9%	-5.02	-0.6%	0.7%
(S57) Non-Metallic Minerals Extraction	-0.44	-3.0%	0.4%	-1.02	-3.0%	0.9%	-25.73	-4.6%	5.5%	-27.20	-4.5%	4.0%
(S42) Commerce	-0.38	0.0%	0.3%	-0.84	-0.1%	0.8%	-5.31	-0.1%	1.1%	-6.53	-0.1%	1.0%
(S5) Other from Extractive Industry	-0.36	-12.3%	0.3%	-0.09	-10.5%	0.1%	-23.11	-4.7%	5.0%	-23.56	-4.8%	3.4%
(S19) Agricultural Defensive Agents	-0.32	-0.3%	0.3%	-0.30	-0.3%	0.3%	-0.60	-0.5%	0.1%	-1.22	-0.4%	0.2%
(S49) Services for Companies	-0.29	-0.1%	0.3%	-0.13	-0.1%	0.1%	-0.63	-0.1%	0.1%	-1.05	-0.1%	0.2%
(S6) Food and Beverage	-0.21	0.0%	0.2%	-1.06	0.0%	1.0%	-1.97	0.0%	0.4%	-3.24	0.0%	0.5%
(S44) Information Services	-0.20	-0.1%	0.2%	-0.05	-0.1%	0.0%	-0.30	-0.1%	0.1%	-0.55	-0.1%	0.1%
(S25) Other Products from Non-Metallic Minerals	-0.16	-0.1%	0.2%	-0.50	-0.1%	0.5%	-2.89	-0.1%	0.6%	-3.55	-0.1%	0.5%
(S18) Pharmaceutic Products	-0.15	0.0%	0.1%	-0.05	0.0%	0.0%	-0.20	0.0%	0.0%	-0.40	0.0%	0.1%
(S59) Production of Glass and their Products	-0.13	0.0%	0.1%	-0.06	0.0%	0.1%	-0.08	0.0%	0.0%	-0.28	0.0%	0.0%
(S3) Oil & Gas	-0.11	-0.2%	0.1%	-0.21	-0.2%	0.2%	-19.60	-0.4%	4.2%	-19.91	-0.4%	2.9%
(S24) Cement	-0.10	0.0%	0.1%	-0.31	0.0%	0.3%	-1.93	0.0%	0.4%	-2.34	0.0%	0.3%
(S46) Estate Services and Rent	-0.09	0.0%	0.1%	-0.04	0.0%	0.0%	-0.29	0.0%	0.1%	-0.42	0.0%	0.1%
(S28) Metal Products - except Machines and Equipments	-0.09	-0.2%	0.1%	-0.08	-0.2%	0.1%	-0.14	-0.2%	0.0%	-0.31	-0.2%	0.0%
(S56) Public Administration and Social Security	-0.07	0.0%	0.1%	-0.02	0.0%	0.0%	-0.21	0.0%	0.0%	-0.30	0.0%	0.0%
(S8) Textiles	-0.07	-0.1%	0.1%	-0.13	-0.1%	0.1%	-0.30	-0.1%	0.1%	-0.50	-0.1%	0.1%
(S32) Machines, Devices and Electric Materials	-0.06	-0.2%	0.1%	-0.04	-0.2%	0.0%	-0.06	-0.1%	0.0%	-0.16	-0.2%	0.0%
(S52) Services for Families and Associatives	-0.05	-0.1%	0.0%	-0.01	0.0%	0.0%	-0.08	0.0%	0.0%	-0.14	0.0%	0.0%
(S29) Machines and Equipments - including Maintanance and Repairs	-0.05	-0.1%	0.0%	-0.06	-0.1%	0.1%	-0.08	-0.1%	0.0%	-0.19	-0.1%	0.0%
(S9) Articles and accessories of Clothing	-0.04	0.0%	0.0%	-0.01	0.0%	0.0%	-0.03	0.0%	0.0%	-0.07	0.0%	0.0%
(S1) Agriculture, Silviculture and Forestry	-0.03	-0.3%	0.0%	-1.05	-0.1%	1.0%	-9.21	-0.1%	2.0%	-10.28	-0.1%	1.5%
(S15) Alcohol	-0.02	-0.2%	0.0%	-1.63	-0.2%	1.5%	-0.95	-0.2%	0.2%	-2.60	-0.2%	0.4%
(S41) Building	-0.02	0.0%	0.0%	-0.01	0.0%	0.0%	-0.06	0.0%	0.0%	-0.08	0.0%	0.0%
(S48) Housing and Food Services	-0.01	0.0%	0.0%	-0.01	0.0%	0.0%	-0.03	0.0%	0.0%	-0.06	0.0%	0.0%
(S37) Parts and accessories for automotives	-0.01	0.0%	0.0%	-0.02	0.0%	0.0%	-0.04	-0.1%	0.0%	-0.07	-0.1%	0.0%
(S39) Furnitures and Other Products from diverse Industries	0.00	0.0%	0.0%	-0.01	0.0%	0.0%	-0.02	0.0%	0.0%	-0.03	0.0%	0.0%
(S51) Commercial Health	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.02	0.0%	0.0%	-0.02	0.0%	0.0%
(S50) Commercial Education	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.01	0.0%	0.0%	-0.02	0.0%	0.0%
(S11) Wood Products - except Furnitures	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%	-0.03	-0.1%	0.0%	-0.03	-0.1%	0.0%
(S36) Trucks and Buses	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S31) Office Machines and Computing Devices	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.01	0.0%	0.0%
(S33) Electronic Materials and Communication Equipments	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.01	0.0%	0.0%	-0.01	0.0%	0.0%
(S4) Iron ore	0.00	-0.1%	0.0%	0.00	0.0%	0.0%	-1.36	-0.1%	0.3%	-1.36	-0.1%	0.2%
(S54) Public Education	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S2) Livestock	0.00	0.0%	0.0%	-0.04	0.0%	0.0%	-0.51	0.0%	0.1%	-0.55	0.0%	0.1%
(S38) Other Equipments for Transport	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.01	0.0%	0.0%
(S10) Leather Goods and Footwear	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.01	0.0%	0.0%	-0.01	0.0%	0.0%
(S55) Public Health	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S7) Products from Smoke (Tobacco)	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S53) Domestic Services	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S34) Devices, Medical instruments	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	-0.01	0.0%	0.0%
(S35) Passenger cars and utilities	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S30) Household Appliances	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S47) Maintanance and Repair Services	1.01	2.7%	-0.9%	-0.02	-0.1%	0.0%	-0.06	-0.1%	0.0%	0.93	0.5%	-0.1%
(S40) Electricity, Gas, Water, Sewage and Urban Cleaning	1.79	0.1%	-1.7%	-3.39	-0.2%	3.1%	-23.28	-0.2%	5.0%	-24.88	-0.2%	3.6%
TOTAL	**-108.24**	**-0.3%**	**100.0%**	**-110.27**	**-0.3%**	**100.0%**	**-465.96**	**-0.3%**	**100.0%**	**-684.46**	**-0.3%**	**100.0%**

APPENDIX K. Impacts over GHG Emissions

Table K 1. Greenhouse Gas (GHG)

2013's SECTORS OF THE ECONOMY	Metropolitan Region of Sao Paulo (MRSP) Δ EMISSIONS OF GHG			Rest of Sao Paulo state Δ EMISSIONS OF GHG			Rest of Brazil Δ EMISSIONS OF GHG			BRAZIL Δ EMISSIONS OF GHG		
	10^6 t CO_2 eq	Sector relevance	Economy relevance	10^6 t CO_2 eq	Sector relevance	Economy relevance	10^6 t CO_2 eq	Sector relevance	Economy relevance	10^6 t CO_2 eq	Sector relevance	Economy relevance
(S0) MBT+WtE	**1.10**	100.0%	-36.8%	-	-	-	-	-	-	**1.10**	**100.0%**	**-23.9%**
(S62) Urban Cleaning Services	-3.90	-49.8%	130.5%	0.00	-0.1%	1.5%	-0.03	-0.1%	2.1%	-3.94	-8.2%	85.4%
(S43) Transport, Storage and Mail	-0.08	-0.2%	2.6%	-0.06	-0.2%	24.8%	-0.30	-0.2%	21.8%	-0.44	-0.2%	9.5%
(S58) Production of Paper, Cardboard and their Products	-0.06	-5.2%	1.9%	-0.06	-4.6%	23.8%	-0.12	-6.1%	8.7%	-0.23	-5.4%	5.1%
(S61) Electricity Production (Oil based)	-0.02	-256.8%	0.7%	-0.01	-256.8%	4.5%	-0.19	-259.0%	13.6%	-0.22	-258.6%	4.8%
(S14) Petroleum Refining and Coke	-0.01	-0.8%	0.4%	-0.03	-0.6%	11.3%	-0.08	-0.5%	5.7%	-0.12	-0.6%	2.6%
(S17) Resins and Elastomers Production	-0.01	-5.8%	0.2%	0.00	-6.1%	1.4%	-0.01	-6.1%	1.0%	-0.02	-6.0%	0.5%
(S26) Steel Production and Derivatives	0.00	-0.1%	0.2%	0.00	-0.1%	1.9%	-0.05	-0.2%	3.7%	-0.06	-0.2%	1.3%
(S13) Newspapers, Magazines and Discs	0.00	-0.1%	0.1%	0.00	-0.1%	0.4%	0.00	-0.1%	0.3%	-0.01	-0.1%	0.2%
(S27) Metallurgy of Non-Ferrous Metals	0.00	-0.1%	0.1%	0.00	-0.1%	0.5%	-0.01	-0.1%	0.4%	-0.01	-0.1%	0.2%
(S23) Rubber and Plastic Articles	0.00	-0.4%	0.1%	0.00	-0.2%	0.4%	0.00	-0.2%	0.2%	-0.01	-0.3%	0.1%
(S16) Chemical Products	0.00	-0.9%	0.1%	0.00	-0.8%	1.0%	-0.01	-1.3%	0.9%	-0.02	-1.1%	0.4%
(S45) Financial Intermediation and Insurance	0.00	-0.1%	0.1%	0.00	-0.1%	0.2%	0.00	-0.1%	0.2%	0.00	-0.1%	0.1%
(S60) Aluminum Metallurgy	0.00	-0.2%	0.1%	0.00	-0.1%	1.1%	0.00	-0.1%	0.3%	-0.01	-0.1%	0.2%
(S22) Products from various Chemicals	0.00	-0.8%	0.0%	0.00	-0.8%	0.4%	0.00	-0.9%	0.1%	0.00	-0.8%	0.1%
(S57) Non-Metallic Minerals Extraction	0.00	-3.0%	0.0%	0.00	-3.0%	0.9%	-0.06	-4.6%	4.1%	-0.06	-4.5%	1.3%
(S24) Cement	0.00	0.0%	0.0%	0.00	0.0%	1.0%	-0.02	0.0%	1.1%	-0.02	0.0%	0.4%
(S49) Services for Companies	0.00	-0.1%	0.0%	0.00	-0.1%	0.1%	0.00	-0.1%	0.1%	0.00	-0.1%	0.1%
(S5) Other from Extractive Industry	0.00	-12.3%	0.0%	0.00	-10.5%	0.1%	-0.05	-4.7%	3.7%	-0.05	-4.8%	1.1%
(S21) Paints, Varnishes and Lacquers	0.00	-0.3%	0.0%	0.00	-0.3%	0.1%	0.00	-0.4%	0.0%	0.00	-0.3%	0.0%
(S20) Perfumery, Health and Cleaning	0.00	-0.2%	0.0%	0.00	-0.1%	0.1%	0.00	-0.4%	0.1%	0.00	-0.3%	0.1%
(S44) Information Services	0.00	-0.1%	0.0%	0.00	-0.1%	0.1%	0.00	-0.1%	0.1%	0.00	-0.1%	0.0%
(S12) Cellulose and Paper Products	0.00	-0.5%	0.0%	0.00	-0.6%	0.3%	0.00	-0.7%	0.3%	-0.01	-0.6%	0.1%
(S3) Oil & Gas	0.00	-0.2%	0.0%	0.00	-0.2%	0.3%	-0.07	-0.4%	4.9%	-0.07	-0.4%	1.5%
(S19) Agricultural Defensive Agents	0.00	-0.3%	0.0%	0.00	-0.3%	0.1%	0.00	-0.5%	0.1%	0.00	-0.4%	0.0%
(S1) Agriculture, Silviculture and Forestry	0.00	-0.3%	0.0%	-0.01	-0.1%	4.4%	-0.10	-0.1%	7.0%	-0.11	-0.1%	2.3%
(S6) Food and Beverage	0.00	0.0%	0.0%	0.00	0.0%	0.5%	0.00	0.0%	0.2%	0.00	0.0%	0.1%
(S46) Estate Services and Rent	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.1%	0.00	0.0%	0.0%
(S28) Metal Products - except Machines and Equipments	0.00	-0.2%	0.0%	0.00	-0.2%	0.1%	0.00	-0.2%	0.0%	0.00	-0.2%	0.0%
(S15) Alcohol	0.00	-0.2%	0.0%	-0.02	-0.2%	7.9%	-0.01	-0.2%	0.8%	-0.03	-0.2%	0.7%
(S25) Other Products from Non-Metallic Minerals	0.00	-0.1%	0.0%	0.00	-0.1%	0.2%	0.00	-0.1%	0.2%	0.00	-0.1%	0.1%
(S18) Pharmaceutic Products	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S32) Machines, Devices and Electric Materials	0.00	-0.2%	0.0%	0.00	-0.2%	0.0%	0.00	-0.1%	0.0%	0.00	-0.2%	0.0%
(S59) Production of Glass and their Products	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S52) Services for Families and Associatives	0.00	-0.1%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S29) Machines and Equipments - including Maintanance and Repairs	0.00	-0.1%	0.0%	0.00	-0.1%	0.1%	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%
(S2) Livestock	0.00	0.0%	0.0%	-0.01	0.0%	3.7%	-0.13	0.0%	9.7%	-0.14	0.0%	3.1%
(S8) Textiles	0.00	-0.1%	0.0%	0.00	-0.1%	0.1%	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%
(S42) Commerce	0.00	0.0%	0.0%	0.00	-0.1%	0.1%	0.00	-0.1%	0.1%	0.00	-0.1%	0.0%
(S41) Building	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S9) Articles and accessories of Clothing	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S48) Housing and Food Services	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S37) Parts and accessories for automotives	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%
(S56) Public Administration and Social Security	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S39) Furnitures and Other Products from diverse Industries	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S51) Commercial Health	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S50) Commercial Education	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S11) Wood Products - except Furnitures	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%
(S36) Trucks and Buses	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S31) Office Machines and Computing Devices	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S33) Electronic Materials and Communication Equipments	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S4) Iron ore	0.00	-0.1%	0.0%	0.00	0.0%	0.0%	0.00	-0.1%	0.2%	0.00	-0.1%	0.1%
(S38) Other Equipments for Transport	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S10) Leather Goods and Footwear	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S54) Public Education	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S7) Products from Smoke (Tobacco)	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S55) Public Health	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S53) Domestic Services	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S34) Devices, Medical instruments	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S35) Passenger cars and utilities	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S30) Household Appliances	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%	0.00	0.0%	0.0%
(S47) Maintanance and Repair Services	0.00	2.7%	-0.1%	0.00	-0.1%	0.0%	0.00	-0.1%	0.0%	0.00	0.5%	-0.1%
(S40) Electricity, Gas, Water, Sewage and Urban Cleaning	0.01	0.1%	-0.3%	-0.02	-0.2%	6.5%	-0.11	-0.2%	8.1%	-0.12	-0.2%	2.6%
TOTAL	**-2.99**	**-3.4%**	**100.0%**	**-0.25**	**-0.2%**	**100.0%**	**-1.37**	**-0.1%**	**100.0%**	**-4.61**	**-0.3%**	**100.0%**