2010

Brazil Low Carbon Case Study

Technical Synthesis Report

WASTE

Coordination:

João Wagner Silva Alves, CETESB
Christophe de Gouvello, The World Bank

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TABLE OF CONTENTS

1. **Executive summary** ---------- 13
2. **Introduction** ---------- 18
3. **Treatment of Municipal Solid Waste (MSW)** ---------- 19
    - 3.1. **Treatment methods** ---------- 19
        - 3.1.1.Sanitary landfills ---------- 20
        - 3.1.2.Incineration ---------- 22
    - 3.2. **Reference scenario - solid waste** ---------- 24
        - 3.2.1.Municipal Solid Waste ---------- 24
        - 3.2.2.Calculation methods ---------- 32
        - 3.2.3.Composting ---------- 33
        - 3.2.4.Estimated GHG emissions from landfill disposal ---------- 34
        - 3.2.5.Estimate of GHG emissions from incineration ---------- 36
        - 3.2.6.Results ---------- 37
        - 3.2.7.Other Technologies and Events ---------- 37
        - 3.2.8.Uncertainties (MSW) ---------- 41
    - 3.3. **Other mitigation options** ---------- 42
        - 3.3.1.Reducing waste generation at source ---------- 42
        - 3.3.2.Composting ---------- 43
        - 3.3.3.Biogas collection and burning ---------- 43
        - 3.3.4.Other benefits ---------- 44
    - 3.4. **Low Carbon Scenario - solid waste** ---------- 46
        - 3.4.1.Low Carbon Scenario for the MSW sector ---------- 47
        - 3.4.2.Consolidation ---------- 47
        - 3.4.3.Results ---------- 50
        - 3.4.4.Barriers and proposed solutions ---------- 52
4. **Sewage and effluent treatment** ---------- 55
    - 4.1. **Treatment modes** ---------- 55
        - 4.1.1.Anaerobic lagoons ---------- 56
        - 4.1.2.Anaerobic digesters ---------- 56
        - 4.1.3.Anaerobic reactors ---------- 57
    - 4.2. **Reference Scenario - sewage and effluent treatment** ---------- 58
        - 4.2.1.Domestic sewage ---------- 58
        - 4.2.2.Industrial effluents ---------- 59
        - 4.2.3.Calculation Methods ---------- 59
        - 4.2.4.Estimate of GHG emissions from sewage and effluent treatment ---------- 60

4.2.5. Results ---------- 61
4.2.6. Uncertainties related to the estimates for the domestic sewage sector ---------- 62
4.3. Mitigation options ---------- 63
4.3.1. Other benefits ---------- 64
4.4. Low Carbon Scenario - sewage and effluent treatment ---------- 65
4.4.1. Low Carbon Scenario for domestic sewage ---------- 65
4.4.2. Low Carbon Scenario for Industrial Effluents ---------- 67
4.4.3. Consolidation ---------- 68
4.4.4. Barriers and proposed solutions ---------- 71
5. Consolidation of Low Carbon Scenario ---------- 72
5.1. Synthesis of Low Carbon Scenario ---------- 72
5.1.1. Results according to states ---------- 73
5.2. Economic analysis ---------- 74
5.3. Costs and benefits ---------- 76
5.3.1. Solid waste ---------- 77
5.3.2. Incineration ---------- 79
5.3.3. Domestic sewage and industrial effluent ---------- 80
5.4. Marginal abatement costs and Break Even Carbon Price ---------- 82
5.4.1. Marginal abatement cost ---------- 83
5.4.2. Break Even Carbon Price ---------- 85
5.5. Financing requirements ---------- 86
6. Conclusion ---------- 88
7. Annexes ---------- 90
7.1. Metropolitan regions ---------- 90
7.1.1. Salvador ---------- 90
7.1.2. Fortaleza ---------- 90
7.1.3. Recife ---------- 91
7.1.4. Belo Horizonte ---------- 91
7.1.5. Rio de Janeiro ---------- 92
7.1.6. São Paulo ---------- 92
7.1.7. Curitiba ---------- 93
7.1.8. Porto Alegre ---------- 93
7.2. CDM projects in the waste and effluents sector in Brazil ---------- 94
7.3. Government programs, plans and actions in the waste sector ---------- 105
7.4. Brazilian regulatory framework for the waste sector (in force in 2009) ---------- 110
8. Bibliography ---------- 112

LIST OF EQUATIONS

Equation 1 -Variation of L_o from 1970 to 2005 ---------- 30
Equation 2 - CH4 emission by First Order Decay Method (FOD) – Tier 2 ---------- 34
Equation 3 - Normalization factor for the sum ---------- 35
Equation 4 - Quantity of waste buried ---------- 35
Equation 5 - Potential generation of CH4 ---------- 35
Equation 6 - Degradable organic carbon ---------- 35
Equation 7 - Fraction of decomposable DOC ---------- 36
Equation 8 - Estimate of CO2 emissions from solid waste incineration ---------- 36
Equation 9 - Estimate of N2O from solid waste incineration ---------- 36
Equation 10 - Estimate of CH4 emissions from anaerobic treatment of sewage and effluents ---------- 60
Equation 11 - Estimate of total organic sewage and effluent ---------- 60
Equation 12 - Estimate of total organic sewage and effluent ---------- 60
Equation 13 - Estimate of emission factor for sewage and effluents ---------- 61
Equation 14 - Weighted mean of MCF ---------- 61

LIST OF TABLES

Table 1 - Reference Scenario: Emissions resulting from treatment of effluents ---------- 25
Table 2 - Variation of L0 from 1970 to 2005 in Brazil's
large geographic regions and estimated median L0 for whole country ---------- 30
Table 3 - IPCC (2000) default data for Methane Correction Factor (MCF) ---------- 31
Table 4 - Scenario versus technology or event ---------- 38
Table 5 - Estimate uncertainties in the MSW sector ---------- 42
Table 6 - Low Carbon Scenario: Avoided MSW emissions ---------- 52
Table 7 - Barriers and mitigation actions related to sanitary landfills ---------- 52
Table 8 - Barriers and mitigation actions related to incineration ---------- 53
Table 9 - Reference Scenario: Emissions due to sewage treatment ---------- 62
Table 10 - Estimate uncertainties in the domestic sewage sector ---------- 62
Table 11 - Estimate uncertainties in the industrial effluent sector ---------- 62
Table 12 - Barriers and mitigation actions related to effluent treatment ---------- 71
Table 13 - Low Carbon Scenario: Total emissions from waste, sewage and effluent treatment ---------- 72
Table 14 - Low Carbon Scenario: Emissions from waste, sewage and effluent treatment (by State) ---------- 73
Table 15 - Growth Acceleration Program (PAC) -Sanitation (2007) ---------- 75
Table 16 - Investment costs related to systems for
mitigating emissions of CH4 in sanitary landfills in Brazil (2005) ---------- 78
Table 17 - Per capita cost (US$) of installing sanitary landfills (at 2030 adjusted prices) ---------- 78
Table 18 - Investment costs related to MSW incineration systems (2008) ---------- 80
Table 19 - Per capita costs (US$) of installing incinerators in Brazil (at 2030 adjusted prices) ---------- 80
Table 20 - Cost of installing sewage treatment ---------- 81

Table 21 - Investment costs of mitigating CH4 emissions in ETEs in 2008 ---------- 82
Table 22 - Costs of installing sewage treatment (at 2030 adjusted prices) ---------- 82
Table 23 - Current abatement costs: 2030 Low Carbon Scenario ---------- 84
Table 24 - Marginal abatement costs, Break Even Carbon
Price and scale of investment for 2030 Low Carbon Scenario ---------- 85
Table 25 - CDM sanitary landfill projects ---------- 95
Table 26 - CDM composting projects ---------- 97
Table 27 - CDM liquid effluents projects ---------- 98
Table 28 - CDM rural waste projects ---------- 98
Table 29 - Government programs, plans and actions in the waste sector ---------- 105
Table 30 - Federal level legal rulings applicable to the waste sector ---------- 110

LIST OF FIGURES

Figure 1 - General strategy employed in elaborating the
2030 scenario for GHG emissions in the waste, sewage and effluents sectors ---------- 14
Figure 2 - Population growth according to PNE (National Energy Plan) 2030 ---------- 15
Figure 3 - Low Carbon Scenario: total emissions from waste, sewage and effluents treatment ---------- 16
Figure 4 - Greenhouse gases produced by the treatment and disposal of solid waste ---------- 19
Figure 5 - Main components of a biogas collection system ---------- 21
Figure 6 - Example of a fluidized bed incinerator ---------- 23
Figure 7 - Scenario 1-A: Reference Scenario for the MSW sector ---------- 25
Figure 8 - Precipitation levels in Brazil[3] ---------- 26
Figure 9 - Total Population Growth in Brazil 1950-2050 ---------- 27
Figure 10 - Total population growth according to the PNE 2030 ---------- 27
Figure 11 Waste Production by municipality (quantity of trash in 2010, 100 tons) ---------- 28
Figure 12 - Waste generation ---------- 29
Figure 13 - Potential generation of CH4 – Lo ---------- 30
Figure 14 - Fraction of fossil carbon in waste ---------- 31
Figure 15 - Operating standardes of landfills in Brazil from 19790-2030 ---------- 32
Figure 16 - General strategy employed in elaborating the
2030 scenario for GHG emissions caused by waste treatment ---------- 32
Figure 17 - Scenario 3-A CH4 burning at 75 percent collection efficiency in landfill ---------- 37
Figure 18 - Scenario 2-A: 20 percent increase of waste mass arriving at landfill ---------- 39
Figure 19 - Scenario 4A: Incineration of 100 percent of
solid waste in municipalities with populations of over 3 milliion inhabitants ---------- 40
Figure 20 - Scenario 5-A: Reduction by 20 percent of quantity of waste delivered to landfills ---------- 40
Figure 21 - Scenario 6-A: Incineration of 100 percent of waste
produced in municipalities with over 3 million inhabitants; CH4 burning
in landfills in municipalities with population between 100,000 and 3,000,000 ---------- 41

Figure 22 - Example of passive drainage well --43
Figure 23 - Example of a forced exhaustion drainage well system --44
Figure 24 - Example of a forced exhaustion system (equipment) ---44
Figure 25 - Scenario 3-A: CH4 burned with 75 percent collection efficiency in landfills --------------------47
Figure 26 - Reference Scenario: MSW services provision --48
Figure 27 - Low Carbon Scenario: MSW services provision --49
Figure 28 - Reference Scenario: Percentage distribution of MSW treatment services ----------------------49
Figure 29 - Low Carbon Scenario: Percentage distribution of MSW treatment services --------------------50
Figure 30 - Low Carbon Scenario 2010-2030--50
Figure 31: Emission from Waste Mt CO2e, by Municipality – Reference Scenario 2030--------------------51
Figure 32: Emissions from Waste, Mt CO2e, by Municipality – Low Carbon 2030----------------------------51
Figure 33 - Sources of GHG emissions caused by effluent treatment ---55
Figure 34 - Sources of sewage and effluents, treatment systems and potential CH4 emissions------------56
Figure 35 - Upflow Anaerobic Sludge Blanket Reactor (UASB) --57
Figure 36 - Scenario 1-B or Reference Scenario for Domestic Sewage ---------------------------------------58
Figure 37 - Scenario 1-C or Reference Scenario for Industrial Effluents --------------------------------------59
Figure 38 - General strategy for elaborating the 2030
Scenario regarding GHG emissions caused by effluent treatment --59
Figure 39 - Reference Scenario for Domestic and Industrial Effluent Emissions -----------------------------61
Figure 40 - Anaerobic lagoon with biogas collection ---63
Figure 41 - Scenario 2-B: 50 percent of domestic sewage
collected and treated anaerobically without burning CH_4 --66
Figure 42 - Scenario 3-B: collection and burning of biogas
generated in some of the domestic sewage treatment systems from 2010-2030 -----------------------------66
Figure 43 - Scenario 2-C: 50 percent of domestic sewage
collected and treated anaerobically without burning CH4. --67
Figure 44 - Scenario 3-C: Burning CH4 generated by treatment of industrial effluents 2010-2030 -------68
Figure 45 - Low Carbon Scenario: Domestic sewage treatment systems ------------------------------------68
Figure 46 - Low Carbon Scenario: Percentage distribution of domestic sewage treatment systems ------69
Figure 47 - Low Carbon Scenario: Percentage distribution of industrial effluent treatment systems -----70
Figure 48 - Low Carbon Scenario: treatment of sewage and effluents--70
Figure 49 - Low Carbon Scenario: Total emissions from treatment of waste, sewage and effluents -------72
Figure 50: Total Emissions (MT CO2e) from Solid Waste, and Sewage and Effluents ------------------------74
Figure 51 - Cost of landfill impelementation (R$/inhabitant) in the state of Minas Gerais ------------------77
Figure 52 - Marginal Abatement Costs ---84
Figure 53 - Break Even Carbon Prices --86
Figure 54 - Scale of Investment--87

Acronyms

ABRELPE - Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais (Brazilian Association of Public Cleansing and Special Waste Companies)
CETESB - Companhia de Tecnologia de Saneamento Ambiental (Environmental Sanitation Technology Company)
CDM - Clean Development Mechanism
BOD - Biochemical Oxygen Demand
EFDB - Emission Factor Database (IPCC-Intergovernmental Panel on Climate Change)
EPA - Environment Protection Agency (US)
FOD - First Order Decay
GHG - Greenhouse Gases
IBGE - Instituto Brasileiro de Geografia e Estatística (Brazilian Geography and Statistics Institute)
ICGCC - Brazilian Interministerial Commission on Global Climate Change (Comissão Interministerial de Mudança Global do Clima)
INMET - Instituto Nacional de Meteorologia (National Meteorological Institute)
IPCC - Intergovernmental Panel on Climate Change
MCIDADES - Ministério das Cidades (Ministry of Cities)
MCT - Ministério da Ciência e Tecnologia (Ministry of Science and Technology)
MMA - Ministério do Meio Ambiente (Environment Ministry)
PAC - Programa de Aceleração do Crescimento (Growth Acceleration Program)
PDD - Project Design Document
PLANSAB - Programa Nacional de Saneamento Básico (National Basic Sanitation Program)
PNE - Plano Nacional de Energia (National Energy Plan)
PMSS - Programa de Modernização do Setor de Saneamento (Sanitation Sector Modernization Program)
PNMC - Plano Nacional de Mudança do Clima (National Climate Change Plan)
PNSB - Pesquisa Nacional de Saneamento Básico (National Basic Sanitation Survey)
UNDP - United Nations Development Program
PPA - Plano Plurianual (Multi-Year Plan)
PROSAB - Programa de Pesquisas em Saneamento Básico (Basic Sanitation Research Program)
MSW - Municipal Solid Waste
SMA - Secretaria Estadual do Meio Ambiente de São Paulo (São Paulo State Environment Secretariat)
SNIS - Sistema Nacional de Informações de Saneamento (National Sanitation Information System)
SSE - Secretaria Estadual de Saneamento e Energia (State Sanitation and Energy Secretariat)
tCO2e - Ton of CO2 equivalent
UNFCCC - United Nations Framework Convention on Climate Change

Acknowledgments

This report synthesis the findings for the waste sector of a broader study, the Brazil Low Carbon Study, which was undertaken by the World Bank in its initiative to support Brazil's integrated effort towards reducing national and global emissions of greenhouse gases while promoting long term development. The study builds on the best available knowledge and to this effect the study team undertook a broad consultative process and surveyed the copious literature available to identify the need for incremental efforts and centers of excellences. It was prepared following consultations and discussions on the scope of the work with the Ministries of Foreign Affairs, Environment and Science and Technology. Several seminars were also organized to consult with representatives of Ministries of Finance, Planning Agriculture, Transport, Mines and Energy, Development, Industry and Trade. Several public agencies and research centers participated or were consulted including EMBRAPA, INT, EPE, CETESB, INPE, COPPE, UFMG, UNICAMP and USP.

The Brazil Low Carbon Study was prepared by a team lead by Christophe de Gouvello, the World Bank and covers four key areas with large potential for low-carbon options: (i) land use, land-use change, and forestry (LULUCF), including deforestation; (ii) transport systems; (iii) energy production and use, particularly electricity, oil and gas and bio-fuels; and (iv) solid and liquid urban waste. The present document is supported by more than 15 technical reports and four synthesis reports for the four main areas. This study was supported by the World Bank through funds made available from the Sustainable Development Network for regional climate change activities and through support from the World Bank Energy Sector Management Assistance Program (ESMAP).

This synthesis report on Waste Treatment was prepared by a team coordinated by João Wagner Silva Alves, CETESB and Christophe de Gouvello, the World Bank, and composed of João Wagner Silva Alves, Bruna Patrícia de Oliveira, George Henrique C. Magalhães Cunha, Tathyana Leite Cunha Alves, Francisco do Espírito Santo Filho, Josilene Ticianelli Vanuzzini Ferrer, Fátima Aparecida Carrara, Rosimeire S. Magalhães Molina, CETESB, Marcos Eduardo Gomes Cunha and Eduardo Toshio, Ciclo Ambiental Engenharia Ltda.

The World Bank supervision team of the whole Low Carbon Study included Christophe de Gouvello, Jennifer Meihuy Chang, Govinda Timilsina, Paul Procee, Mark Lundell, Garo Batmanian, Adriana Moreira, Fowzia Hassan, Augusto Jucá, Barbara Farinelli, Rogerio Pinto, Francisco Sucre, Benoit Bosquet, Alexandre Kossoy, Flavio Chaves, Mauro Lopes de Azeredo, Fernanda Pacheco, Sebastien Pascual and Megan Hansen.

1. Executive summary

The following report on the 2030 Low Carbon Scenario for the waste management sector in Brazil is divided into seven sections. The first section describes the context in which the report was prepared. Cooperation between the World Bank and CETESB (Companhia de Tecnologia de Saneamento Ambiental / *Environmental Sanitation Technology Company*) made it possible for some of the material assembled for the Reference Report on greenhouse gas emissions of Brazil's waste sector between 1990 and 2005[1] to be usefully employed in the preparation of the 2030 scenario. The CETESB website (www.cetesb.sp.gov.br/biogas) contains key data obtained during this exercise. The information is available for public viewing and can be published if required. During the preparation of the CETESB Reference Report, a permanent Inventory Network was established. The network assists with providing relevant data and continues to make a valuable contribution to the online discussion forum coordinated by the CETESB technical team.

The second section of the report addresses the Reference Scenario and the Low Carbon Scenario for 2030 for the solid waste sector, possible ways of mitigating GHG, and the technologies employed in the different scenarios. The maintenance of the existing conditions in the solid waste Reference Scenario, with the addition of the capture and burning of landfill CH_4, basically defines the Low Carbon Scenario of the solid waste sector. Other technologies, such as incineration or reduction of the amount of waste liable for disposal in landfills, are also discussed, together with estimates of the emissions produced. In addition to Low Carbon Scenario considerations, the technologies for reducing GHG emissions are discussed in detail in order to enable readers to assess the impact of the individual technologies on greenhouse gas generation.

The third section addresses the Reference Scenario and 2030 Low Carbon Scenario of the domestic sewage and industrial effluents sectors. The maintenance of the present conditions described in the sewage and effluents sector Reference Scenario, together with the installment of anaerobic treatment systems (anaerobic digestion) endowed with devices for capturing and burning CH_4, basically define the Low Carbon Scenario for the sewage and effluents treatment sector. Anaerobic digestion can be deployed with the use of anaerobic lagoons, anaerobic upflow reactors, sludge blanket digestion or other processes which work on the basis of absence of oxygen. The remaining technologies for reducing GHG emissions are considered separately. The benefits associated with low carbon waste management practices (for solid waste, domestic sewage and industrial effluents) are listed in Sections 2 and 3.

The fourth section discusses the projected Low Carbon Scenario for 2030, the various hypotheses posited, and the key results. This section also contains an economic cost analysis and examines the Break Even Carbon Price and other financial aspects of the implementation of the Low Carbon Scenario in the solid waste and domestic sewage and industrial effluents sectors.

The fifth section of the report presents the main conclusions of the study, while the sixth and seventh sections contain bibliographical references and annexes respectively.

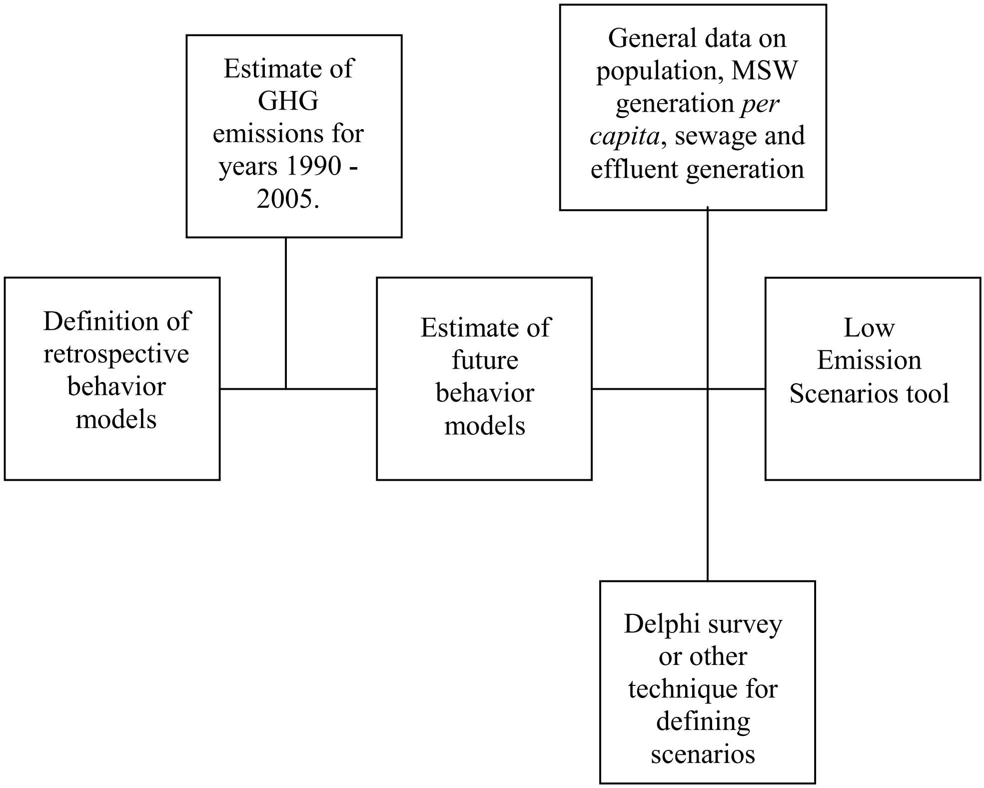
The method employed for elaborating the Low Carbon Scenario in the solid waste sector and the domestic sewage and industrial effluents sectors is illustrated in Figure 1. A series of

1 The Reference Report on countrywide greenhouse gas emissions produced by waste and effluent treatment in the period 1990-2005, was prepared by CETESB In cooperation with the Ministry of Science and Technology and the United Nations Development Program (UNDP). The Report forms part of the National Communication on GHG emissions.

predominantly linear mathematical models played a major role in estimating GHG emissions, employing data which recorded the past behavior of the following: the quantities of solid waste and sewage generated on a *per capita* basis, industrial effluent loads, the composition of solid waste, sewage and industrial effluents, quality standards of landfill operations, treatment technologies employed, levels of methane recovery, etc. This data was used in accordance with the IPCC (Intergovernmental Panel on Climate Change) (2000) method for estimating emissions in the Low Carbon Scenarios.

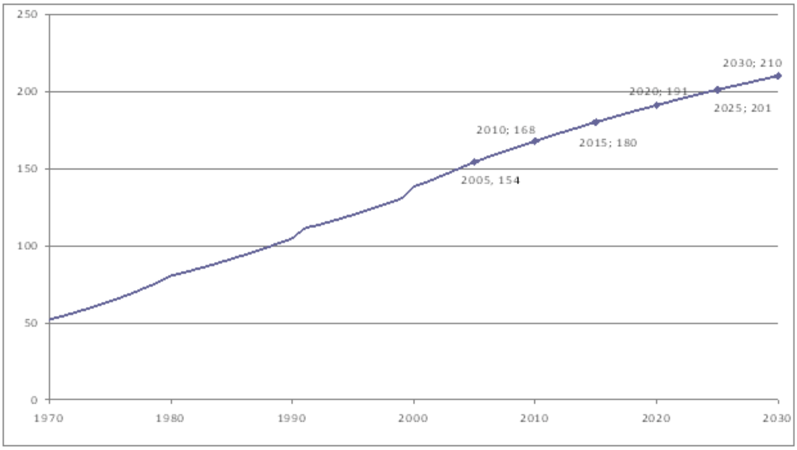
The IPCC method also provided *default* emission factors when these could not be located in the relevant Brazilian technical literature. Estimates of the behavior of the same retrospective data were then formulated for the period between 2010 and 2030. These data and assumptions provided the basis for this study's definition of the Reference and Low Carbon Scenarios of the waste sector in Brazil.

Figure 1 - General strategy employed in elaborating the 2030 scenario for GHG emissions in the waste, sewage and effluents sectors



The data employed in the preparation of this scenario were obtained from locally available literature wherever available. The first factor considered was population growth. The Brazilian Ministry of Mines and Energy estimates, for example, that by year 2010, 168 million people will be living in urban areas in Brazil (see Figure 2), rising to 210 million by 2030. Based on this official data, a year-by-year estimate was made of the population and examined other key features (where available in the literature) for each of the approximately 5,500 municipalities.

Figure 2 - Population growth according to PNE (National Energy Plan) 2030



Source: IBGE, 1970, 1980, 1991 e 2000 e PNE, 2007

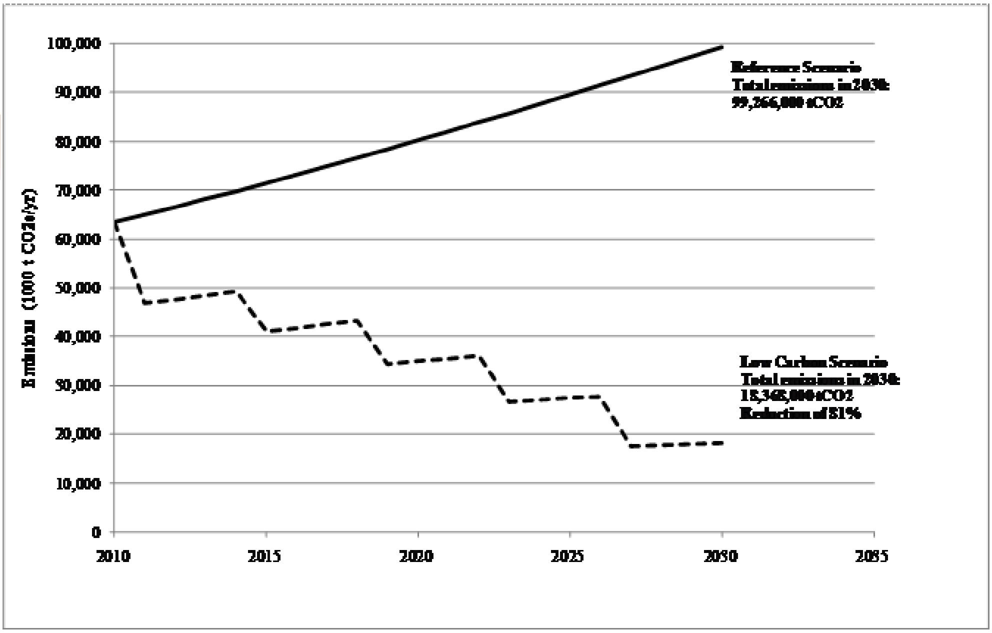
On the basis of the road map depicted in Figure 1, the models tracking the behavior of variables which influenced past emissions and which impact current sanitation policies were defined. It is expected that behavior models over the next few decades will also be affected by population growth, urbanization, rates of *per capita* waste generation, composition of waste, etc.

Estimates were made of GHG emissions relating to waste management in Brazil over the past 20 years. Using Figure 1 again, together with some of the data from Figure 2, projections were made of the waste, sewage and effluents sector Reference Scenario. Estimates were also made of the possible GHG emissions resulting from the different technologies employed and, finally, once the Low Carbon emissions had been identified, the costs and investment requirements for introducing GHG abatement methods were examined. The relevant values were calculated on the basis of a discount rate of 8 percent or 12 percent a year.

The results in Figure 3 below show that the total GHG emissions of the waste sector could reach, according to the Reference Scenario, around 99.26 $MtCO_2e$/year by 2030, representing an increase of over 40 percent in the level of emissions observed for year 2010. However, if the proposed Low Carbon Scenario is successfully adopted, 75 percent[2] of the emissions from landfills could be abated by simply installing collection and burning systems, while a further 5 percent of the emissions could be avoided by constructing anaerobic systems for treating sewage by collecting and destroying CH_4. The result would be an overall reduction of emissions in the waste sector from 99.26 $MtCO_2e$/ year to under 18.36 $MtCO_2e$/ year by 2030.

2 According to the MDL landfill projects (MCT, 2009), biogas capture efficiency is of the order of 75 percent.

Figure 3 - Low Carbon Scenario: total emissions from waste, sewage and effluents treatment



The majority of emissions in the solid waste sector arise from current waste management methods. Seventy eight percent of such emissions are avoidable (in all, 962.69tCO_2e can be avoided at a cost of US$1.3/t$CO_2$e). On the other hand, the emissions that can be avoided as a result of the treatment of domestic sewage and industrial effluents account for 22 percent of the total, amounting to 30.40 tCO_2e and 238.35tCO_2e respectively.

However, compared to the low costs associated with the installation of CH_4 collection and burning systems in landfills, the costs of installing anaerobic systems for sewage/effluent CH_4 collection and methane burning are estimated at around US$930.38/t$CO_2$e for domestic sewage and approximately US$103.30/t$CO_2$e for industrial effluent treatment. These costs do not take into account the benefits associated with the reduced pollution resulting from the non-dumping of substantial organic loads into water bodies. Water pollution caused by raw sewage and industrial effluents is widespread in Brazil and will inevitably continue if the Reference Scenario is maintained, involving the non-treatment and collection of around 50 percent of all the domestic sewage and industrial effluents produced.

Among the alternatives considered for for the future waste management scenario in Brazil, an increase in the quantities of waste for disposal in landfills was included, at levels over and above the ones indicated in the Reference Scenario. This could result from a rise in income levels of the population leading to increased consumption levels and consequently higher levels of waste generation. Increased landfill disposal could also result from heavier government investment in the sanitation sector aimed at expanding waste collection and other services. According to ABRELPE (2008) 15 percent of waste is currently not collected. Increases in waste collection and disposal using current practices would produce higher GHG emissions (see Figure 18).

The suggested Low Carbon Scenario which maintains the conditions defined in the Reference Scenario, and adds the burning of CH_4, could combine some of the downside factors considered in this report (e.g. increased quantities of waste for landfill disposal) with more positive sanitation and environmental benefits. While the Low Carbon Scenario draws on projections of specific waste management behavior patterns likely to influence GHG emissions, the scenario also reflects the beneficial outcomes which could emerge from the implementation of the Federal Government's current public policies, programs, and plans in the waste management area. Finally, consideration is given to some of the obstacles and facilitating mechanisms impacting the waste sector developments between 2010 and 2030.

2. Introduction

The purpose of the present report is to assist in the preparation of public policy proposals regarding greenhouse gas emissions and the additional financial resources necessary.

With the support of a waste sector-related Inventory Network (see www.cetesb.sp.gov.br/biogas for more details), CETESB has developed tools for estimating GHG emissions produced by waste treatment. With a view to better evaluate the behavior of the variables used in the IPCC (2000) method, the resulting data is still the subject of discussion by the above mentioned network.

The GHG produced by waste treatment consists of CH_4 from the anaerobic digestion of organic material contained in solid wastes, domestic sewage and industrial effluents, CO_2 from the fossil fraction of incinerated solid waste, and from N_20, also produced by waste incineration.

The estimated scenarios draw upon a number of factors such as the evolution of the variables involved (which have a bearing on past emission estimates), current sanitation policies, anticipated demographic growth, the spread of urbanization and rising levels of *per capita* waste and its components over the next 20 years.

The main purpose of the scenarios is to provide an evaluation of the GHG emissions arising from the different approaches and methods for treating waste and to ensure that important environmental aspects are taken into account when key decisions are being made on the waste treatment technologies to be applied in Brazil.

For the 2030 Low Carbon Scenario on waste treatment, the PNE (Plano Nacional de Energia / *National Energy Plan*) (2030) urban population projections were used. The PNE (2007) estimated that the country's urban population in 2005 was 154,343,300 and forecasts an urban population of 209,918,700 by 2030- representing demographic growth of 36 percent over the 25-year period. The scenario also reflects the possible results of the Federal Government's current policies, programs, and plans in the waste management sector. Obstacles and facilitating mechanisms likely to influence developments in the country's waste sector between 2010 and 2030 were also taken into consideration.

3. Treatment of Municipal Solid Waste (MSW)

The various technical methods for waste treatment mentioned in this report represent only a sample of the numerous ways of treating solid waste available in the scientific literature. The descriptions in this study relate only to those municipal solid waste treatment technologies for which the IPCC (2000 and 2006) methods provide data and/or guidance for calculating GHG emissions, and where the existence of *default* values can be verified, and therefore pre-established emission factors for each type of waste treatment technology can be calculated. The treatment technologies considered in this study are outlined below.

3.1. Treatment methods

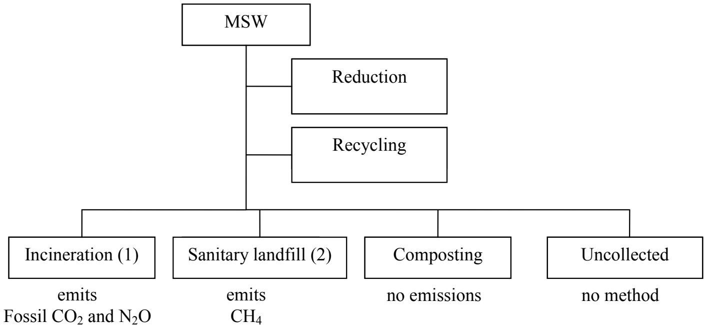
According to the IPCC (2000) burying and incinerating solid wastes produces GHG emissions(see Figure 4). Other alternative methods such as recycling, increasing collection frequency, etc. involve increased or reduced waste deposited either in landfills or incinerated. Composting is considered to be one of the methods for mitigating or sequestering GHG.

The possibility also exists of treating MSW with anaerobic digestion in sanitary landfills or through high temperature thermal treatment. Incineration is the most commonly used method in Brazil. As for anaerobic digestion in sanitary landfills, the decomposition of organic waste material and the possibility of using the CH_4 for power generation purposes is discussed.

The IPCC (2006) method covers the following types of incineration: continuous, semi-continuous and batch load (*batelada*) employing grid or fluidized bed technologies. 'Continuous' incineration involves the use of incinerators which do not require switching on and off on a daily basis. On the other hand, 'semi-continuous' or batch load incinerators must usually be switched on and off at least once a day. The operational differences among the three types of incinerators explain why each of them produces different GHG emissions data.

Figure 4 illustrates the alternatives considered which provide the basis for estimating the amounts of GHG emitted (or avoided) in the 2030 Scenario.

Figure 4 - Greenhouse gases produced by the treatment and disposal of solid waste



Comment:
(i) The incineration techniques are listed according to the equipment employed, as follows:
- continuous grate or fluidized bed incinerator (fossil CO_2 and N_2O emissions)
- semi-continuous grate or fluidized bed incinerator (fossil CO_2 and N_2O emissions)
- batch load grate or fluidized bed incinerator (fossil CO_2 and N_2O emissions).
(ii) In addition to disposal in a sanitary landfill or treatment in an aerobic reactor for subsequent landfill disposal with a reduction of the Chemical Oxygen Demand (COD) of the MSW:
- anaerobic digestion (emission of CH_4).

3.1.1. *Sanitary landfills*

The Brazilian Technical Norms Association (ABNT) defines a sanitary landfill for municipal solid waste as follows:

> *"... a sanitary landfill is a method for disposing of MSW in the ground without causing hazards or risks to public health and safety, minimizing environmental impacts. This method employs engineering principles in order to restrict the waste to the smallest area possible and to reduce it to the lowest permissible volume, thereafter covering it with a layer of earth at the end of each working day or at shorter intervals if necessary..."*
> (ABNT NBR 8419, 1984).

Treatment of municipal solid waste in sanitary landfills is based upon the anaerobic (oxygen free) digestion of the organic material present through bacteriological processes leading to decomposition.

Anaerobic digestion of waste produces biogas - a mixture of different gases: CH_4, carbon dioxide (CO_2), hydrogen (H_2) and sulphuric acid (H_2S). The CH_4 component represents on average between 50 percent and 80 percent of the total volume of gas, while carbon dioxide gas accounts for between 5 percent and 20 percent. The composition of the purified biogas is similar to natural combustible gas and is therefore a worthwhile alternative for use as a source of energy (ALVES, 2000).

According to the IPT/CEMPRE (2000), sanitary landfills can be classified into three different types depending on the way in which they are constructed:

1) the "trench" or "ditch" method where the waste is deposited in open trenches at the disposal site. It is usually employed in areas where the subsoil can be easily excavated;

2) the progressive slope or "ramp" method, based upon excavation of an access ramp and the disposal of waste, which is subsequently compacted by tractor and then covered with earth. This method is used in areas which can be excavated and where soil can be used to provide a covering layer; and

3) the "area" method, used in places with flat topography and a shallow water table.

According to IPT/CEMPRE (2000) the operating sequence of a sanitary landfill commences with garbage trucks being weighed at the site entrance. After weighing, the trucks are subjected to an inspection of their loads and then directed to the disposal position depending on the zoning arrangements in the landfill. Finally, the trucks are weighed again at the exit.

After the waste is deposited, compacting and leveling the waste should be done by crawler tractors or landfill tractors with compaction wheels. At the end of the working day the deposited waste must be covered with an appropriate layer of earth which on average should be 0.2m thick. The combination of the layer of waste and the soil cover is called a "cell". The aim of covering the waste with a layer of soil is to avoid the proliferation of disease-carrying insects, to facilitate movement by the various vehicles and other machines on the site, and to render the surface of the landfill more impermeable to prevent rainwater from affecting the layers of waste underneath (CEMPRE, 2000).

In order to ensure ideal operating conditions, a sanitary landfill must possess drainage systems for rainwater, percolated liquids, and biogas. The purpose of the rainwater drainage system is to stop it from infiltrating into the waste. This type of system normally comprises a network of concrete channels and pipes designed to collect the water in the appropriate places.

The drainage system for percolated liquids is designed to collect and channel liquids for appropriate treatment. The latter can be done in a treatment station on the landfill site itself or in off-site facilities. The aim of this type of system is to prevent percolated liquids from leaching into and contaminating the water table and nearby water bodies. The system basically consists of rows of small channels dug directly into the ground or located on an impermeable layer in the landfill and filled with filtering material (CEMPRE, 2000).

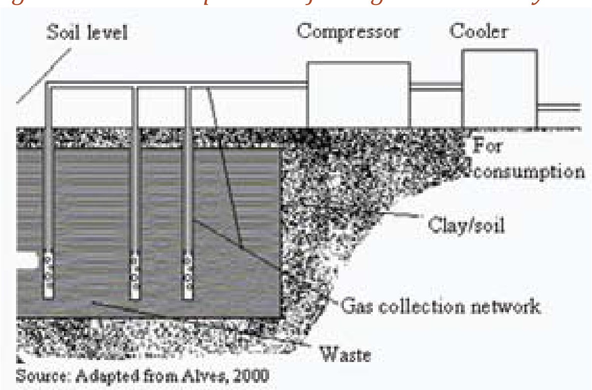
According to the PROSAB (2003), a biogas drainage system is used to collect and treat the biogas generated by the anaerobic decomposition of the organic material present in the waste. It also aims to minimize potential fire risks and bad odors caused mainly by the presence of sulphidric gas in the biogas. The gases are captured by means of vertical extraction pipes rising from the bottom of the landfill and discharging the biogas at an exit point above the top layer of earth. Similar to chimneys, these drains are basically rows of perforated pipes surrounded by sleeves of gravel of an equal thickness to that of the diameter of the tubes used (IPT/CEMPRE, 2000).

The employment of these vertical extraction pipes is the simplest and most common way of capturing biogas, although Henriques (2004) claims that an alternative method is to collect the biogas through horizontal 'drains' installed at the time of laying down the different levels of waste. The main advantage of this process is that biogas can be collected from the beginning of the waste disposal operation (from the lowest layers of the landfill upwards) without the operators having to wait for the landfill to be completely covered (CEMPRE, 2000).

Brazil possesses only two sanitary landfills which use biogas CH_4 for burning and energy generation. The most common practice at present is to allow the gas to escape directly into the atmosphere through collector drains.

A standard biogas collection system is based upon three key components: collection shafts and conductor pipes, a compressor and treatment system, as illustrated in Figure 5. The majority of energy recovery systems possess a burner used for flaring off excess gas or for use during equipment maintenance periods (MUYLAERT et. al., 2000; OLIVEIRA, 2000).

Figure 5 - Main components of a biogas collection system



The collection pipes have their upper ends connected to horizontal tubes which transport the biogas to a main collector. The biogas is pumped out of the landfill cells and then forced by the compressor through the transmission tubes to the power generation plant (WILLUMSEN, 2001). The compressor is used to transfer the biogas from the collection pipes and is also normally employed to compress the gas before it enters the energy recovery system.

The treatment system is also designed to capture and discard the condensate which forms in the collection system. When the hot biogas produced by the sanitary landfill passes through the system, it cools and forms a condensate which, if not removed, can block the collection system and reduce the efficiency of the energy recovery process. Control of the condensate normally begins in the collection system, where descending tubes and connectors are used to drain it into tanks or collection traps. The condensate is then generally discharged into the public wastewater network, into a local treatment system or recirculated within the landfill itself (MUYLAERT et. al., 2000). As for the CH_4, when this has been correctly treated it is considered to be ready for consumption.

3.1.2. *Incineration*

Incineration is a waste treatment technology (known as thermal treatment) involving the combustion of organic waste materials for conversion into less bulky, toxic or atoxic substances, or in certain cases for eliminating it altogether (CETESB, 1993).

According to Lora (2002) one of the advantages of incineration compared to MSW treatment using sanitary landfills is that, unlike the latter, it avoids the problems caused by the generation and treatment of leachates and permanent gaseous emissions. On the other hand, the disadvantages of this type of waste treatment include the need for larger start-up investments and higher ongoing operating costs.

Employing incineration for waste disposal requires the installation of systems to deal with the polluting gases generated as a result of the combustion process of certain components in the solid waste. In the majority of cases electrostatic or fabric filters are used to counter these emissions (LORA, 2002).

Grate incinerators

Grate incinerators are used for burning MSW either in its raw or “treated” state. The latter is the result of a process involving the separation of recyclable MSW aimed at removing hazardous, bulky or recyclable materials (similar to that employed in composting). This produces a less bulky and more uniform material than the original raw waste and is easier to incinerate (IPT/CEMPRE, 2000).

A plant containing grate incinerators normally is comprised of two or three combustion units operating in parallel, each with a capacity of between 50 to 100 tons per day. These facilities are assembled on-site and modern versions possess a combustion chamber lined with water-wall tubes, used for recovering energy, and gas-cleaning systems (IPT/CEMPRE, 2000).

The MSW incineration process involves the following (IPT/CEMPRE, 2000): the MSW, after being weighed, is tipped into a pit where it is thoroughly mixed and blended by a series of waste grabs suspended on overhead gantries. These grabs are also used for loading the material into the feeder silo, from where it is loaded by means of hydraulic pistons into the incinerator combustion chamber.

The moving (descending) grate propels the waste through the combustion chamber, allowing for efficient and complete combustion at high temperatures. During its transit through the boiler the material heats up and dries out at the same time as it loses volatile organic compounds, before traveling down to the pit at the other end where a small quantity of organic material is generally still present in the form of ash. This type of grate can operate with different-sized materials, which makes it appropriate for incinerating MSW in its raw state.

Around 60 percent of the combustion air is supplied through the grate from below and the remainder enters the boiler and is applied to the burning waste through nozzles over the grate. The airflow entering from below serves to cool the load and assist in drying and burning the waste. Meanwhile, the air injected at high pressure from above facilitates complete combustion of the flue gases by introducing rapid turbulence for better mixing of the combustion gases and fumes generated during the process of thermal decomposition. The temperature in the area over the grate can reach around 1200°C, leading to the destruction of most of the components in CO_2 and water.

The high-temperature flue gases are then cooled in heat exchangers, which convert the heat into steam, which can then be used for electricity generation or heating purposes. The flue gases, cooled to around 250°C , are then dispatched to the flue gas-cleaning systems where acid gases, particulates, dioxins, heavy metals and furans are removed.

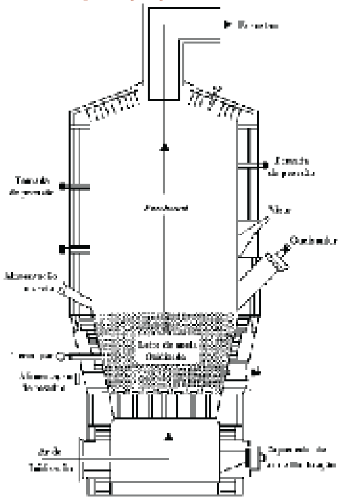
On exiting the grate the organic fraction of the MSW should be almost totally burned, leaving a predominantly inorganic fraction called 'incinerator bottom ash'. In practice a small organic fraction is contained within this ash in the form of carbon. The bottom ashes are extinguished in a water lock and then dispatched for final disposal in landfills.

The steam generated in this way can be used as a source of heat for generating steam-based power and/or electricity. The system involving dual steam and electrical energy generation is known as 'co-generation'.

Fluidized-bed incinerators

A fluidized bed incinerator consists of a combustion chamber, a porous plate or distributor, a waste feeder system, and an auxiliary fuel system, illustrated in Figure 6 (OLIVEIRA, 2007).

Figure 6 - Example of a fluidized bed incinerator



Source: Adapted from Theodore and Reynolds, 1987

According to the IPT/CEMPRE (2000), in fluidized-bed incinerators an inert material such as aluminized sand or calcium carbonate is kept suspended by a powerful pumped airflow ('fluidization air') injected into the base of the sand bed. The suspended sand layer behaves like a liquid and at the beginning of the operation is heated by auxiliary burners located above the bed. When the temperature reaches around 400°C a 'fluidized bed' is created, and waste can be introduced either from above or within the bed. The intense mixing and churning in the bed has the effect of distributing the solid waste uniformly throughout the furnace. The small particles of solid waste are affected by the intense heat of the sand (which constitutes 95 percent of the mass of the bed), which heats, drys and combusts rapidly. When the operating temperature of around 600°C is reached, the auxiliary burners are switched off and the operation from that point onwards primarily consists of ensuring a continuous supply of waste and continuously removing the ash generated by the process.

The ash produced by incineration is collected in gas-cleaning systems or removed at regular intervals from the base of the bed. Harder materials such as metals are also removed at regular intervals from the base together with other ash clinker.

The organic compounds removed from the bed either in solid or gaseous form are burnt in the upper area of the sand bed. This area acts as an after-burner, with secondary air injected at high pressure to cause significant turbulence for burning the remaining organic compounds, with gas temperatures rising to around 900°C. The ratio of secondary to primary air is generally of the order of 2/1. The bed temperature is maintained at around 600°C in order to avoid problems with the fusion and agglomeration of individual sand particles.

After the gases pass through the upper area they move to the energy recovery and gas treatment systems.

While fluidized bed incinerators are widely used to burn municipal, agricultural, petrochemical and medical waste (OLIVEIRA, 2007) their most common application is the incineration of sewage sludges.

This equipment has a number of drawbacks such as the need for waste to be pre-sorted, either by sifting or milling, in order to reduce the components to a maximum particle size of 2.5cm. Operational problems also tend to occur given the constant need to replace the inert substances due to particulate fouling on the sand layer.

Fluidized bed incinerators do, however, offer a number of advantages: high gas-to-solid ratios, high bed-to-surface heat transfer coefficients, high turbulence levels both at the gas and solid interaction phases, uniform temperatures in the incinerator furnace and the potential for neutralizing acid gases on-site with carbonate or lime.

3.2. Reference scenario - Solid Waste

The MSW treatment Reference Scenario was estimated based on forecast population growth, future rates of per capita waste generation, changes in waste composition over the years and localized regional disparities. All these subjects are dealt with in detail under Item 3.2.1 below.

3.2.1. Municipal Solid Waste

The MSW waste sector Reference Scenario presupposes that Brazil's current sanitation situation remains unchanged. In this report attention is drawn to the various initiatives, mainly taken at the federal level, to improve the present situation. It is clear that these measures will take time to be implemented and for this reason the Reference Scenario in this study is based upon the assumption that current conditions will continue.

The Reference Scenario is based upon the hypotheses described below and illustrated by Figure 7, which provides an estimate of the emissions likely to occur. It can be seen that CH_4 emissions increase from approximately 55,000 tCO_2e in year 2010 to over 73,000 tCO_2e by 2030. This increase reflects population growth in urban areas as projected by the Ministry of Mines and Energy (PNE, 2007).

Figure 7 - Scenario 1-A: Reference Scenario for the MSW sector

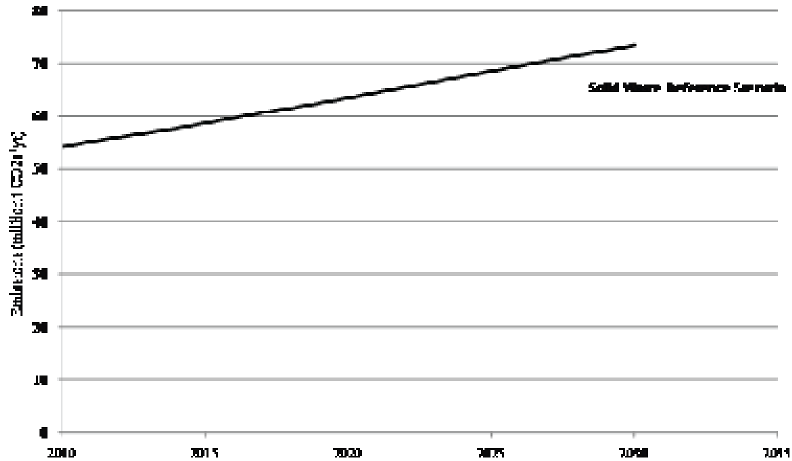


Table 1 below lists the GHG emissions of the MSW sector Reference Scenario for the years 2010, 2015, 2020, 2025 and 2030. In the 20-year period from 2010 to 2030 the emissions are expected to increase by 35.6 percent.

Table 1 - Reference Scenario: Emissions resulting from treatment of effluents

Year	Emissions from MSW treatment
	(1000tCO_2e)
2010	54,200
2015	58,732
2020	63,630
2025	68,610
2030	73,473

The Reference Scenario for GHG emissions in the solid waste sector was estimated by considering the variables employed by the IPCC (2000) method. The following are examples of data examined: urban population (IBGE, Instituto Brasileiro de Geografia e Estatística / *Brazilian Geography and Statistics Institute* and EPE), the *per capita* rate of collected waste (ABRELPE), the quality of local waste disposal operations, waste composition, climate (INMET-

Instituto Nacional de Meteorologia / *National Meteorological Institute*) and IPCC *default* emission factors. A substantial amount of information relevant to the discussion of waste management was not used since it was decided that this was unlikely to contribute objectively to the IPCC-related estimates (e.g. composting, the influence of scavenger cooperatives, at-source waste reduction, reuse of waste materials, recycling campaigns, etc).

In addition to the MSW sector Reference Scenario, simulations were constructed of certain other treatment modes or technologies. A simulation was done, for example, of increased quantitative waste collection possibly flowing from improvements in local authority collection services or from increased personal consumption levels unaccompanied by effective programs to encourage the reduction of at-source waste generation. A simulation was also done of the larger quantities of waste which could arise from worsening of waste collection services or the introduction of successful selective collection, recycling, or composting programs. A further simulation concerned the introduction of incinerators in a number of Metropolitan Regions. Finally, the Low Carbon Scenario dealt solely with the collection and burning of CH_4 in cities throughout the entire country under the same conditions as defined in the Reference Scenario.

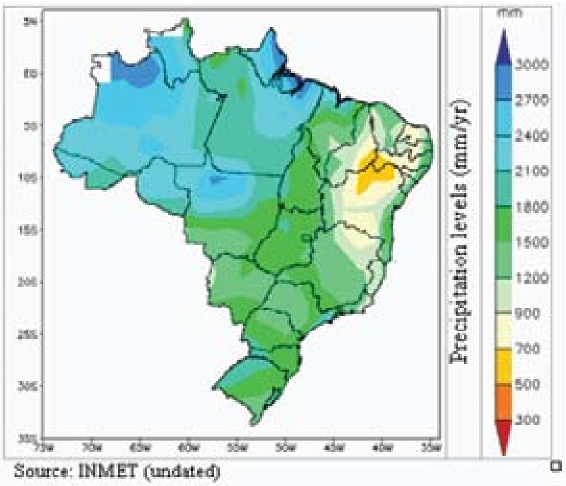
The Reference Scenario was based on variables according to the IPCC (2000) method explained under item 3.2.2 (calculation methods) below.

Decay potential -"k".

K and *A* are variables that depend on climate. The IPCC (2006) default data are the most appropriate for estimating emissions in Brazil. Two standard data elements were used for *k* as suggested by Jensen and Pipatti, (2002) apud IPCC (2006), based upon a weighted mean of MSW composition where degradation was different for each type of waste and also differed in the mixture of wastes. Given the scarcity of data about waste composition in the Brazilian literature and its effect on *k*, default emission factors for mixed residues were adopted and estimated according to climatic zone and average precipitation levels.

In order to identify the rainfall situation in different areas of Brazil, INMET data were employed based on 1960-1990 records for the municipal areas listed in Annex 1.

Figure 8 - Precipitation levels in Brazil[3]



3 Annual accumulated rainfall for the period 1961-1990

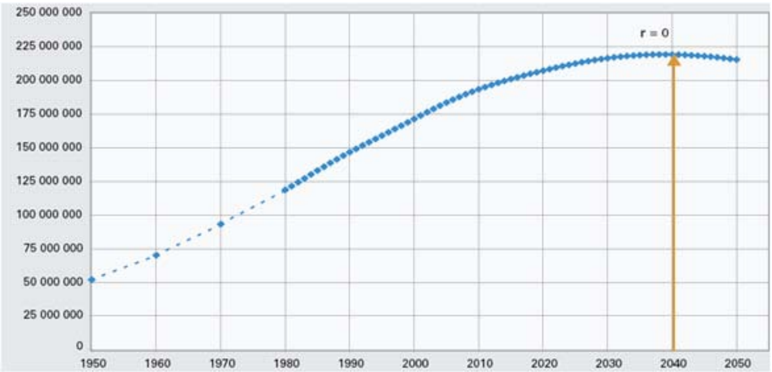
Figure 8 shows rainfall data for Brazil's five large geographic regions:

- North Region: MAP (mean annual precipitation) > 1000mm/yr, therefore *k* = 0.17.
- Northeast Region: varies where MAP < 1000mm/a is equal to 0.065 and MAP>1000mm/yr, therefore *k* = 0.17.
- Center-West Region: MAP>1000mm/yr, therefore *k* = 0.17.
- Southeast Region: MAP>1000mm/yr, therefore *k* =l 0.17.
- South Region: MAP>1000mm/yr, therefore *k* = 0.09.

Quantity of waste collected – Rx

The *Rx* was estimated on the basis of IBGE population census data for 1970, 1980, 1991, and 2000. The population projection for 2005-2030 was taken from the PNE 2030 figures (2007). The intermediate years between 2001 and 2004 were estimated assuming uniform exponential growth in the period between the 2000 Census and PNE figures for the year 2005.

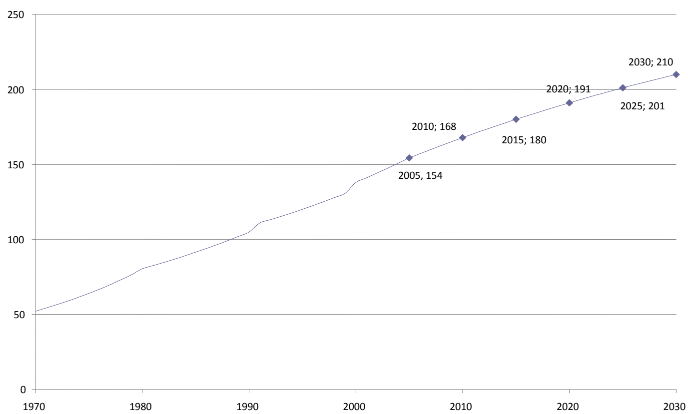
Figure 9 - Total Population Growth in Brazil 1950-2050



Source: IBGE, 2007

It can be observed in Figure 9, that in year 2030 a total population of around 220 million is projected according to IBGE. Meanwhile, PNE 2030 has estimated an urban population of 209,918,900 for the same year (Figure 10).

Figure 10 - Total population growth according to the PNE 2030

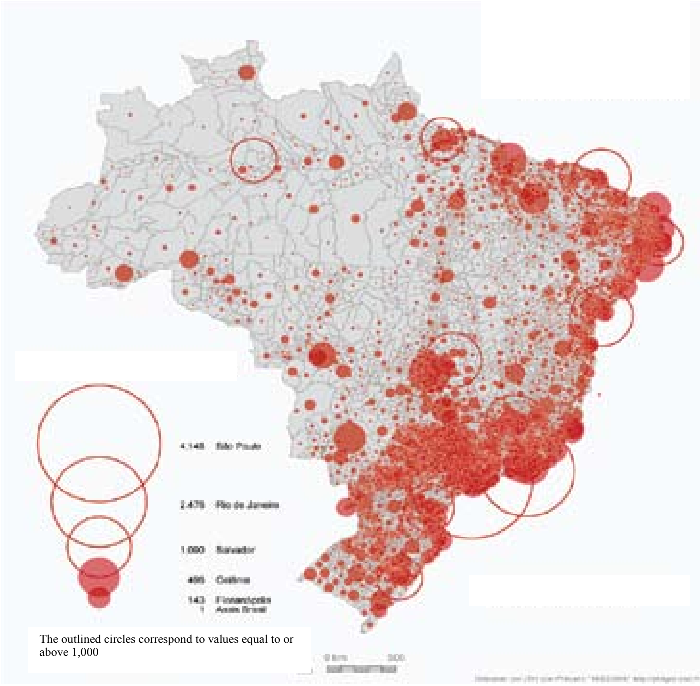


Source: IBGE (1970, 1980, 1991 and 2000) and PNE 2007

Waste generation-MSW

The estimate of waste generation in Brazil was done using *per capita* waste generation data provided by CETESB/SMA (Secretaria Estadual do Meio Ambiente de São Paulo / *São Paulo State Environment Secretariat)*(1998) and ABRELPE (2008) for the period between 1970 and 2005. The later years were estimated on the basis of a continuing rate of growth for *per capita* waste generation and an increased urban population in each of the municipalities. Waste produced by municipality in 2010 is shown in Figure 11.

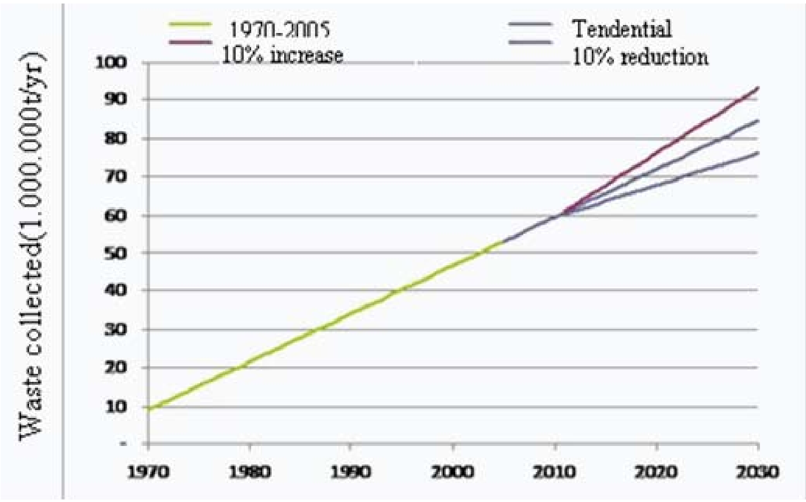
Figure 11 – Waste Production by municipality (quantity of trash in 2010, 100 tons)



Source: CETESB, World Bank Brazil Low Carbon Case Study

This scenario presupposes that measures undertaken for encouraging at-source waste generation reductions, such as environmental education programs, changes in household waste disposal, or programs aimed at promoting recycling, could result in an overall reduction in waste generation of around 10 percent. On the other hand, improved waste collection services could in practice increase the present quantity of MSW collected (85 percent) by up to 15 percent (ABRELPE, 2007). Other factors, such as increased personal incomes or enhanced consumption patterns, could also contribute to boosting the amount of waste collected. Figure 12 below depicts the historical data for waste generation from 1970-2005, and the tendential trajectory veresus a 10 percent increase and decrease in waste generation.

Figure 12 - Waste generation



According to PNSB (2000) data, 80 Mt/year of urban waste was collected in Brazil in 2000, amounting to 1.6 kg/per person/per day. This information was updated on the basis of surveys done by the Ministry of Cities and the Brazilian Environment Ministry. A set of data produced by ABRELPE in 2007 assessed the quantity of collected waste per capita at 0.9 kg/per person/per day. The latter took into account the rolling surveys and studies undertaken by both the above ministries and are regarded as more reliable than the above-mentioned PMSB figures. These were adopted as a basis for the Scenario. CETESB data for the 1970s (between 0.4 and 0.7 kg/per person/per day) was also used, and for the period between 1970 and 2005 the linear variation of the CETESB rate was estimated, while in subsequent years the higher quality ABRELPE[4] data was used.

Potential for generating CH4-Lo

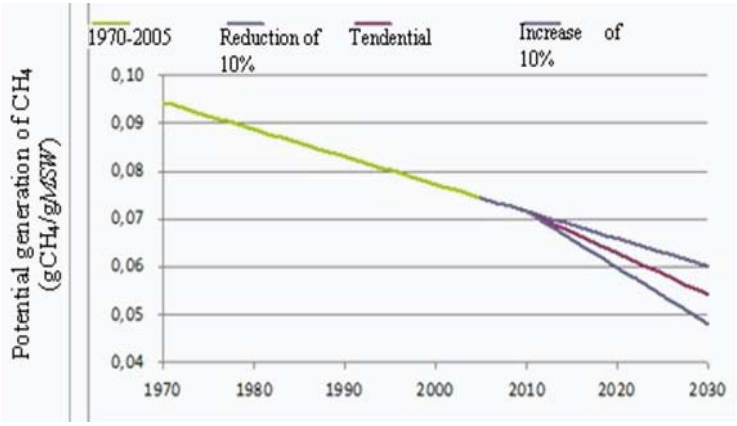
Determination of the variation of CH_4 generation potential was done on the basis of a sample of 95 analyses of the composition of waste collected in different municipalities between 1970 and 2005. This data provided the basis for estimating changes in the behavior of waste components over time. The variation is illustrated by Figure 13. The Reference Scenario is represented by the continued reduction of this potential verified between 1970 and 2005. Factors such as the reduction of the proportion of waste components responsible for generating CH_4 in the MSW or an increase in the number of inert substances causing this reduction could accelerate reduction by around 10-20 percent. The latter estimated reduction was a result of in-house discussion by experts involved in preparing the Reference Scenario, and such a figure has not appeared in any other publication.

4 The MSW rate for the year 2005 was estimated only for the 5 macro regions in the country:

Region	Angular Coefficient	Linear Coefficient
North	0.000433	0.5064
Northeast	0.000254	0.7054
Southeast	0.000216	0.5864
Midwest	0.000384	0.6136
South	0.000357	0.5015

Source: ABRELPE, 2007.

Figure 13 - Potential generation of CH4 – Lo



On the basis of the aforementioned data, the variation of L_0 between 1970 and 2005 for the country's five large geographic regions was estimated on the basis of the equation below.

Equation 1 – Variation of $\mathbf{L_0}$ from 1970 to 2005

$$L_0(t) = Angular\ coefficient\ .\ t + Linear\ coefficient$$

Where:

$L_0(t)$	Estimate for L_0 variation over time	[$GgCH_4$/GgMSW
t	Estimate year	[year]
Angular coefficient	Angular coefficient	[$GgCH_4$/GgMSW.year]
Linear coefficient	Linear coefficient	[$GgCH_4$/GgMSW]

Table 2 represents the application of the above equation to Brazil's five large geographic regions for the years 1970-2005.

Table 2 - Variation of L0 from 1970 to 2005 in Brazil's large geographic regions and estimated median L0 for whole country

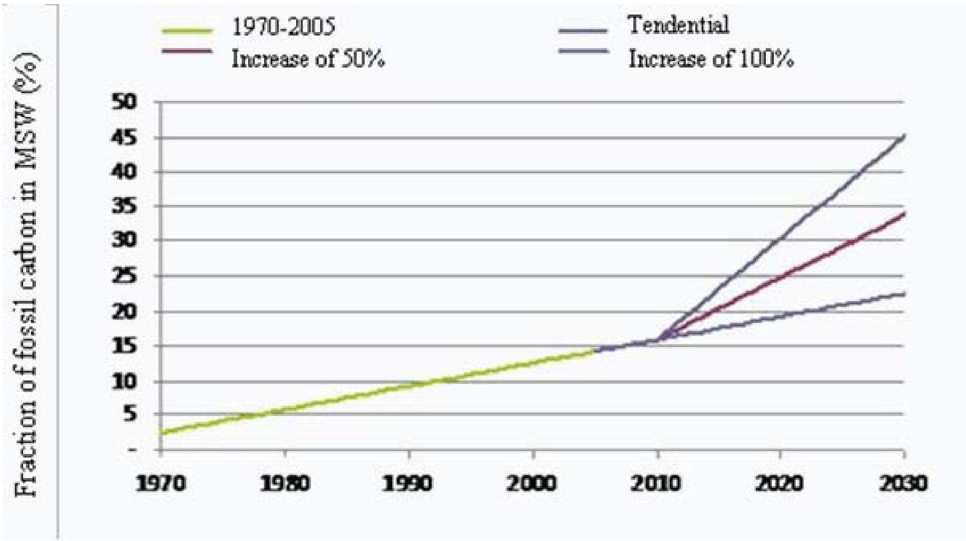
Region	Angular coefficient [$GgCH_4$/GgMSW.yr]	Linear coefficient [$GgCH_4$/GgMSW]
North	-0.0009474001	1.9768323166
Southeast	-0.0006538087	1.3855212029
South	-0.0007001260	1.4758037577
Northeast	-0.0001240116	0.3212859891
Center-West	+0.0012000000	2.2899000000
Brazil	-0.0005687632	1.2147400398

On the assumption that the evolution of the L_0 for the Center-West region was based on only three items, it was decided to employ the median regression of the entire country covering all the data referring to the remaining regions. The above table provided the basis of estimating CH_4 emissions arising from MSW disposal in landfills during the 15-year period from 1990 to 2005.

Fraction of carbon fossil waste - CCW. FCF

Using the same set of data employed for determining L_0, it was possible to determine the fraction of carbon fossil waste for the years 1970 to 2005. Future evolution was based simply on assuming the continuity of past trends. Higher concentrations of carbon fossil fractions can be verified as a result of increased use of packaging, more intensive distribution of food and beverages, reductions in the price of consumer products manufactured by the petrochemical industry, or by the straightforward reduction of the portion of waste that could be described as biomass.

Figure 14 - Fraction of fossil carbon in waste



Methane Correction Factor - MCF

The MCF varied according to the operating quality standards of the MSW disposal sites. Table 3 shows the IPCC (2000) *default* data on which (from a brief description of the disposal sites) the MCF can be estimated.

Table 3 - IPCC (2000) default data for Methane Correction Factor (MCF)

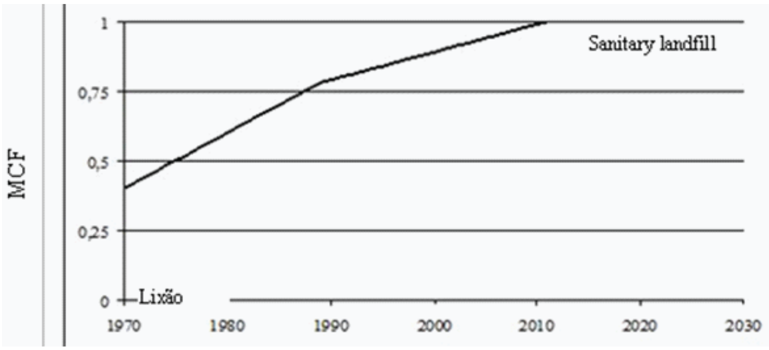
Type of MSW disposal site	MCF
Sanitary landfill	1.0
Unmanaged landfill of over 5m deep	0.8
Unmanaged landfill of under 5m deep	0.4
Disposal of unclassified trash	0.6

Source: IPCC, 2000

In the Reference Scenario it was estimated that municipalities with under 200,000 inhabitants in 2030 will continue to run unmanaged waste disposal sites of up to 5m deep (MCF = 0.4).

The remaining municipalities with populations of over 200,000 in 2030 had a methane correction factor which evolved from 1970 (the worst situation) to an 'intermediate' status in 1990 and, finally, to a proper sanitary landfill from 2010 onwards. In this respect the Reference Scenario estimate differed from that outlined in the IPCC method. It was assumed that the transition from one situation to another occured in a gradual fashion and continued over the years, although this was not taken into account in the above method. On a year-on-year basis the MCF increased from 0.82 to 1.0 without any estimate being made of intermediate data between one estimate and another. See Figure 15.

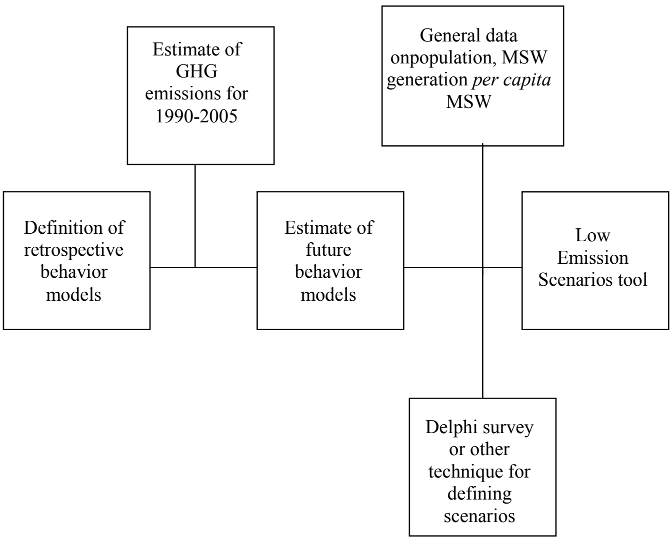
Figure 15 - Operating standards of landfills in Brazil from 19790-2030



3.2.2. *Calculation methods*

The elaboration of the GHG low emission scenario for the year 2030 (Scenario 2030) for waste treatment employed the IPCC (2000) international inventory method and the method described below for defining the Low Emission Scenario. This latter method was adapted and applied as follows.

Figure 16 - General strategy employed in elaborating the 2030 scenario for GHG emissions caused by waste treatment



As can be observed in Figure 16, the construction of Scenario 2030 began with the definition of models illustrating behavioral patterns in the recent past which appeared to be relevant to the present study. These were mainly linear regression models focused on waste generation rates per urban resident, waste composition, CH_4 generation capacity per unit of waste mass, and fossil carbon fractions, providing a benchmark for evaluating the behaviors most likely to characterize this scenario.

Estimate of GHG emissions resulting from waste treatment

The method employed for estimating the GHG emissions arising from waste treatment in Scenario 2030 was also used in the preparation of the Reference Report on waste sector GHG emissions contained in the National Communication. The GHG estimate was obtained using the IPCC (2000) method.

Waste treatment or disposal methods

The model developed by CETESB for defining the quantities of GHG susceptible to mitigation and the additional resources needed for achieving the Low Carbon Scenario is described below.

The CETESB model applies the IPCC (2000) method for estimating GHG emissions. The activities related to the treatment and disposal of gas-generating solid waste and effluents are appropriately identified.

The model used in this study (based on the IPCC 2000 method) considers the following sites for the disposal of solid waste: MSW disposal sites which could be classified as 'sanitary' landfills, 'unmanaged' landfills of over 5m deep and 'unmanaged' landfills of under 5 m deep. In all these sites the organic material contained in the waste continued to produce CH_4 for between 30 and 50 years (the most common occurrence in Brazil). A waste disposal method which further breaks down the waste is incineration, but this is done on an insignificant scale in Brazil. Incineration can be accompanied (or not) by employing heat recovery and electricity generation technologies. Generation of waste can of course be reduced by introducing programs to encourage a lower level of waste at-source generation or by boosting recycling and composting programs.

MSW is not fully collected in all the municipalities, which makes it difficult to maintain minimum public health standards in Brazilian towns and cities. However, improvements in the country's sanitary conditions have led to larger quantities of waste being deposited in more suitable places, therefore alleviating some of the problems arising from the pollution caused by uncollected waste.

On the other hand, improvements in the operation of disposal sites can bring about an increase in GHG. According to the IPCC (2000), greenhouse gas emissions from an identical quantity of waste in an unmanaged landfill of under 5m deep are reduced by 40 percent and, in a landfill of over 5m deep, by 80 percent. This does not mean that 'unmanaged' landfills are more desirable than 'sanitary' landfills. Rather, it means that improvements in the disposal sites must be accompanied by measures which make it viable to collect and destroy the GHG emitted by such sites.

3.2.3. *Composting*

GHG emissions from composting are not addressed by the IPCC (2000) method, which was adopted for elaborating the Low Carbon Scenarios and is also being used as a basis for assessing GHG inventories in Brazil.

The most commonly-used composting method for treating municipal and household waste is the 'aerobic composting technique' which involves decomposition by microorganisms which survive only in the presence of free oxygen. In other words, the aerobic composting process calls for forced aeration (natural and/or artificial ventilation) with the presence of oxygen (O_2) but without the presence of GHG anthropogenic emissions in the digestion process. Composting, an alternative that leads to removing organic material from landfills, presents an excellent opportunity to produce high-quality organic compost. Given that this is an aerobic process, no greenhouse gases are produced and the emission of CH_4 (normally generated in a landfill over a period of some decades) is avoided.

The method defined by the IPCC (2000) provides no guidance on the estimation of emissions arising from composting. Although IPCC (2006) suggests a method, it is not being utilized, since it does not to conform to the National Inventory which is based on two methods: the 1996 IPCC Revised Guidelines for National Greenhouse Gas Inventories and the IPCC (2000) version of the same document.

Other waste management methods include practices for reducing waste generation at source by controlling waste items and changing consumption patterns and habits, or reusing and recycling material – all of which could contribute significantly to reducing the need for energy imputs, raw materials, and natural resources while simultaneously reducing environmentally-hazardous pollutants.

3.2.4. *Estimated GHG emissions from landfill disposal*

In this scenario the method utilized for estimating emissions arising from landfills is the First Order Decay (FOD) method, explained in the IPCC Good Practices Guide published in 2000.

The equation used in the IPCC guidelines for estimating CH_4 emissions of the decay method (*Tier 2*) is described below (Equations 2 - 7).

Equation 2 - CH4 emission by First Order Decay Method (FOD) – Tier 2

$$Q = \sum \left[\left(A.k.RSUt.RSUf.L_0.e^{-k(t-x)} - R \right) \left(1 - \varnothing \right) \right]$$

where:

Q	= *Quantity of* CH_4 *generated per year*	*[GgCH$_4$/yr]*
A	= *Normalization factor for the sum*	*[dimensionless]*
K	= *Decay constant*	*[1/ yr]*
MSWt	= *Total quantity of waste generated*	*[GgMSW/ yr]*
MSWf	= *Fraction of waste to be disposed of in landfill*	*[dimensionless]*
L_0	= *Potential generation of* CH_4	*[GgCH$_4$/GgMSW]*
T	= *Year of calculation*	*[yr]*
R	= CH_4 *recovery*	*[GgCH$_4$/ yr]*
OX	= *Oxidation factor*	*[dimensionless]*

The estimate of *A* employed in Equation 2 can be explained as follows :

Equation 3 - Normalization factor for the sum

$$A = \frac{1-e^{-k}}{k}$$

The estimate of the quantity of waste for disposal in landfills (*Rx*), was calculated on the basis of the product between MSW*t* and MSW*f* and the product between rate MSW*f* and Pop_{urb}.

Equation 4 - Quantity of waste buried

$$MSWt\ .\ MSWf = Rx^2 = \text{rateMSW}\ .\ Pop_{urb}$$

where:

Rx	= *Quantity of waste buried*	*[GgMSW/yr]*
rateMSW	= *Collected waste per capita*	*[kgMSW/inhab.day.]*
Pop_{urb}	= *Urban population*	*[inhab]*

The estimate of L_0 employed in Equation 2 is explained as follows:

Equation 5 - Potential generation of CH4

$$L_0 = MCF\ .\ DOC\ .\ DOCf\ .\ F\ .\ 16/12$$

where:

MCF	= *Methane correction factor related to disposal site management*	*[dimensionless]*
DOC	= *Degradable organic carbon*	*[gC/gRSU]*
DOCf	= *Fraction of the DOC subject to decomposition*	*[dimensionless*
F	= *Fraction of* CH_4 *in the landfill*	*[dimensionless[3]]*
16/12	= *Carbon conversion ratio (C) to* (CH_4)	*[dimensionless]*

The estimate employed in Equation 5 can be explained as follows:

Equation 6 - Degradable organic carbon

$$DOC = (0{,}4\ .\ A) + (0{,}17\ .\ B) + (0{,}15\ .\ C) + (0{,}3\ .\ D)$$

where:

0,4.	= *Degradable organic carbon of the fraction of waste related to paper and textiles*	*[gC/gMSW]*
0.17	= *Degradable organic carbon of the fraction of waste originating in gardens, parks and other putriscible non-food sources*	*[gC/gMSW]*
0.15	= *Degradable organic carbon of the fraction of food-waste*	*[gC/gMSW]*
0.3	= *Degradable organic carbon of the fraction of waste from wood and straw*	*[gC/gMSW]*
A	= *Fraction of waste from paper and textiles*	*dimensionless*
B	= *Fraction of waste originating in gardens, parks and other putriscible non-food sources*	*dimensionless*
C	= *Fraction of food-waste*	*dimensionless*
D	= *Fraction of waste from wood and straw*	*dimensionless*

The estimate of the *DOCf* employed in Equation 5 is explained as follows:

Equation 7 - Fraction of decomposable DOC

$$DOCf = 0.014.T + 0.28$$

where:

T	= *Temperature*	*[°C]*[4]

3.2.5. Estimate of GHG emissions from incineration

Equation 8 - Estimate of CO2 emissions from solid waste incineration

$$Q_{CO_2} = \sum_i (IW_i . CCW_i . FCF_i . EF_i . 44/12)$$

where:

Q_{CO_2} = *quantity of carbon dioxide during per year [GgCO_2/yr]*
i = *MSW: Domestic solid waste*
HW: Hazardous waste
MW: Medical waste
SS: Sewage sludge

IW	= *Mass of waste incinerated by type i*	*[GgMSW/yr]*
CCW	= *Carbon content of the type i*	*[gC/gMSW]*
FCF	= *Fraction of fossil carbon in type i waste*	*dimensionless*
EF	= *Burning efficiency of the incinerators of type i waste*	*dimensionless*
44/12	= *Conversion of C to CO_2*	*dimensionless*

Equation 9 - Estimate of N2O from solid waste incineration

$$Q_{N_2O} = \sum_i (IW_i . EF_i).10^{-6}$$

where:

Q_{N_2O} = *Quantity of nitrous oxide generated per year [GgN_2O/yr]*
i = *MSW: Domestic solid waste*
HW: Hazardous waste
MW: Medical waste
SS: Sewage sludge

IW	= *Mass of waste incinerated by type i*	*[Gg/yr]*
EF	= *Emission factor i*	*[kgN_2O/Gg]*

As is well known, solid waste management can be undertaken using different technologies in addition to landfill disposal or the incineration methods addressed in this report. These technologies can also produce GHG emissions.

Elaboration of this scenario using the IPCC 2000 inventory method considered the technologies contained in that document. The 2000 method (together with the 1996 method) is employed by countries throughout the world to gauge local GHG emissions.

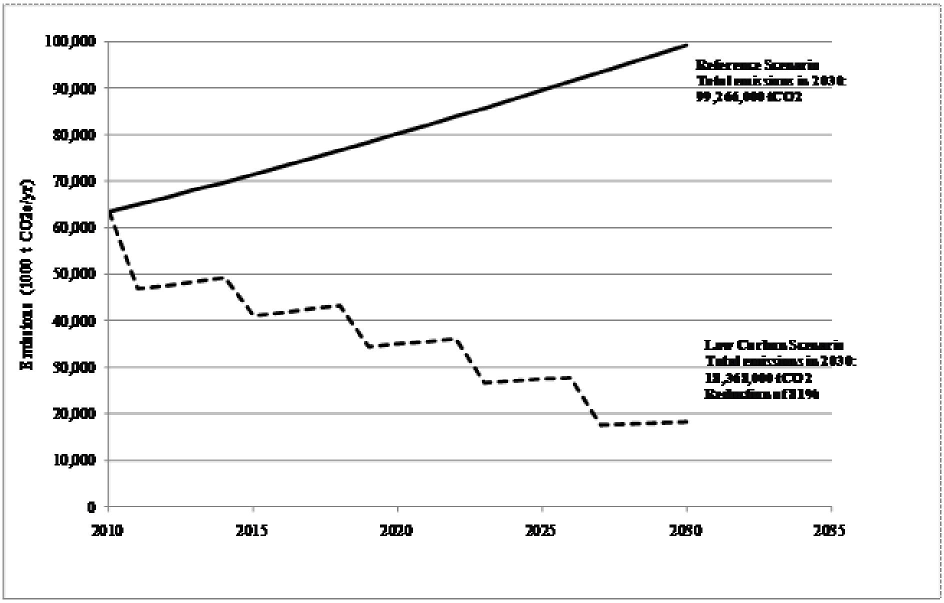
3.2.6. *Results*

Scenario 3-A: Burning CH_4 with a 75 percent collection efficiency in all landfills in Brazil

The practice of burning CH_4 in Brazil began once the Kyoto Protocol entered into force (previously CH_4 was not burned). In April 2009, 30 CDM (Clean Development Mechanism) projects using this method were being dealt with in Brazil´s Inter-Ministerial Global Climate Change Commission. The remaining features of the Reference Scenario have been retained with the exception of the destruction of landfill CH_4 increasing to 75 percent of collection capacity. This is a guideline being applied to CDM projects, even though no national publications confirm this information.

As can be expected, GHG emissions were reduced by 75 percent from the verified total in the scenario without CH_4 burning, and the emissions curve increased in line with population growth and the other variables contained in the Reference Scenario. This scenario forecasts reductions from 73 to18 Mt CO_2e in year 2030, corresponding to 75 percent burning capacity.

Figure 17 - Scenario 3-A CH4 burning at 75 percent collection efficiency in landfill



3.2.7. *Other technologies and events*

In this section the GHG emissions arising from the use of four different waste management technologies or possible events in Brazil are discussed and estimated. The tool used for elaborating scenarios can be accessed on the CETESB website (www.cetesb.sp.gov.br/biogas), and these documents discuss the four scenarios that show the impacts of these alternatives. For example the possible increase in the amount of waste deposited in landfills, which could be caused by improved delivery of municipal sanitation facilities or by increases in family incomes leading to higher consumption and consequent higher waste generation, is estimated. Addtionally, the possible reduction of waste is estimated, due to the possible decline of sanitary services or the reduction of income, consumption and therefore waste.

Waste reductions could also result from environmental education programs designed to encourage waste reduction, reuse and recycling at source. Given the increasing limitations on waste disposal sites in large cities, the possible effects of installing incinerators is also estimated. Finally, assuming that the conditions outlined in the Reference Scenario are maintained, the effects of CH_4 landfill burning are estimated. Discussion of the scenarios in Table 4 below will hopefully provide a clearer idea of the effects of introducing the four different alternatives.

Table 4 - Scenario versus technology or event

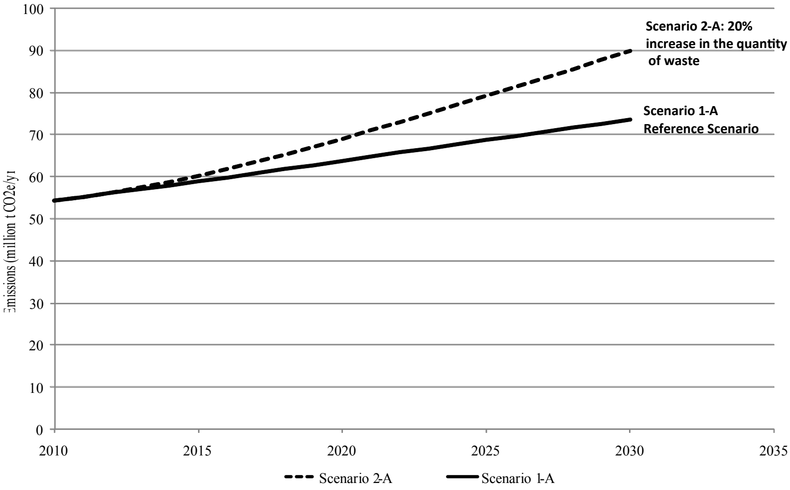
Scenario	Technology or event
1-A	Reference Scenario
2-A	Increase of 20 percent in the waste mass arriving at landfill
3-A	Low Carbon Scenario of the solid waste sector–burning of CH_4 at 75 percent collection efficiency in 100 percent of the landfills in Brazil
4-A	Incineration of 100 percent of waste in MR with populations of over 3 million
5-A	Reduction of 20 percent of quantities of waste for disposal in landfills
6-A	Incineration of 100 percent of the waste in MRs with a population of over 3 million, burning of CH_4 in landfills in municipalities with populations of between 100,000 and 3,000,000

These technologies or events are considered independently given that in most of the results presented there is no simultaneity of events. The main aim is to permit evaluations of the GHG emissions of the different possible alternatives *vis-à-vis* the Reference Scenario. The estimates of emissions take into account all the remaining original conditions defined in the Reference Scenario.

Scenario 2-A: An increase of 20 percent in the waste mass delivered to landfills

According to ABRELPE (2008) 15 percent of Brazil´s MSW is uncollected. The first item to be evaluated involves possible increases in the waste mass earmarked for disposal in landfills (practically the only waste disposal method used in Brazil today). This situation could actually deteriorate as the result of higher levels of efficiency employed by the municipal services responsible for collecting waste. As already mentioned, 15 percent of waste today in Brazil is not collected. A further factor that could influence higher levels of landfill waste is the possible increased prosperity of the population and a consequent increase in the levels of consumption and generation of waste. An increase of GHG generated by landfills from 73 to 89 Mt CO_2e by year 2030 is entirely foreseeable.

Figure 18 - Scenario 2-A: 20 percent increase of waste mass arriving at landfill

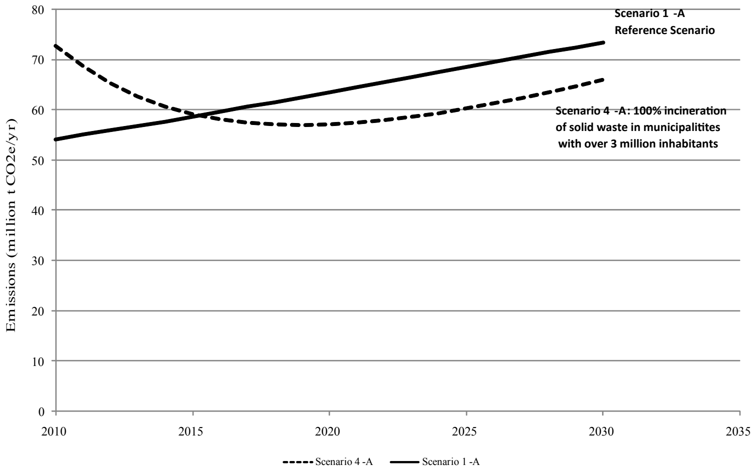


Scenario 4-A: Incineration of 100 percent of waste in MR with populations of over 3 million

A further consideration is the imminent exhaustion of sites in the large Metropolitan Regions for installing landfills. Therefore, one alternative that needs to be considered is waste incineration. As can be seen in Figure 14, the concentration of fossil materials[9] in waste has continued to increase over recent years - from 3 percent in 1970 to 15 percent in 2005. Scenario 4-A considers that this upward trend will continue and that the fossil fraction in waste will continue to increase in a linear, uniform rate up to year 2030.

The increased levels of GHG emissions observed during the early years following the installation of incinerators and closure of landfills in the Metropolitan Regions can be explained by the scale of emissions caused by burning waste and by the continuing emissions from landfill sites. Landfill waste is likely to affect the atmosphere for some decades after the landfills have been taken out of operation. On a more positive note, at the end of the 6th year following the installation of incineration technology, the Scenario 4-A emissions (see Figure 19) equalled those of the Reference Scenario, and in subsequent years a reduction of the emissions was observed. While a reduction from 73 to 66 Mt of CO_2e is estimated for year 2030, this rate of reduction will tend to narrow as the result of the higher concentrations of fossil fractions in the waste being incinerated.

Figure 19 - Scenario 4A: Incineration of 100 percent of solid waste in municipalities with populations of over 3 million inhabitants

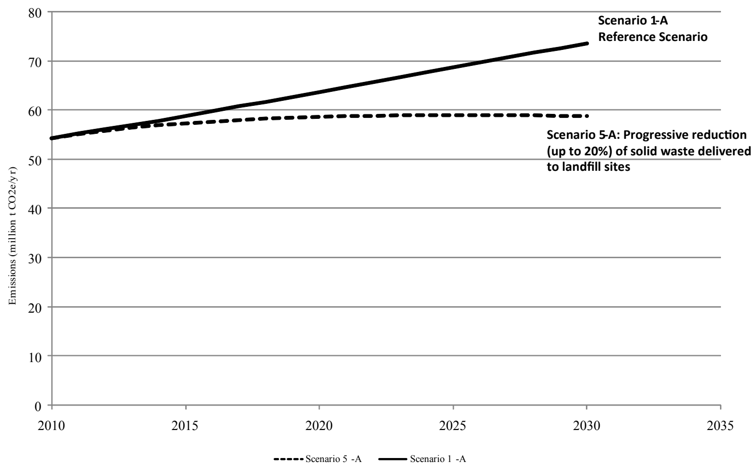


Scenario 5-A: Reduction of 20 percent of quantities of waste for disposal in landfills

A further possibility is to seek to reduce actual waste generation. Natural reduction could be brought about by (i) an economic crisis which would lower levels of consumption and, as a result, reduce MSW generation, (ii) the spread of environmental education programs aimed at reducing waste generation at source, (iii) upscaling waste separation and recycling practices at source or (iv) providing incentives for sustainable consumption whereby people adopt environmentally-friendly habits in their daily routines and are persuaded to generate smaller amounts of waste. All this could lead to a reduction in the quantity of waste for disposal in public landfill sites. Figure 20 illustrates an estimated reduction of around 20 percent of disposable landfill waste in 2030, which would result in a reduction of emissions from 73,000 to 59,000 Gt CO_2e that year.

The initiatives described above could be widely adopted in all the municipalities.

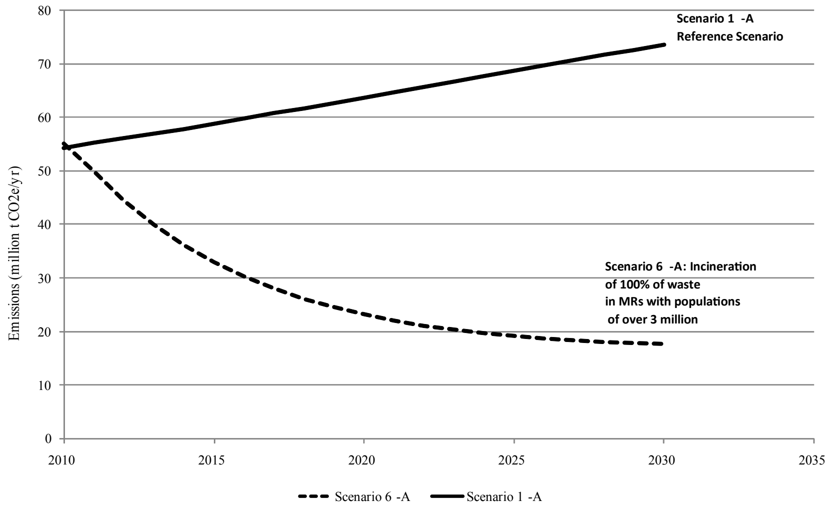
Figure 20 - Scenario 5-A: Reduction by 20 percent of quantity of waste delivered to landfills



Scenario 6-A: Incineration of 100 percent of the waste in MRs with a population of over 3 million, burning of CH_4 in landfills in municipalities with populations of between 100,000 and 3,000,000

The scenario, illustrated in Figure 21 estimates an incineration rate of 100 percent of all the waste in the Metropolitan Regions of Brazil with populations of over 3 million (as in Scenario 4-A) and in cities with populations of between 100,000 and 3 million, where CH_4 would be burned in landfills at 75 percent efficiency rate. This would result in a reduction of emissions from 73 to 17.7 Mt CO_2e in year 2030. In addition to the above considerations, 100 percent of fossil[5] waste would be recycled.

Figure 21 - Scenario 6-A: Incineration of 100 percent of waste produced in municipalities with over 3 million inhabitants; CH4 burning in landfills in municipalities with population between 100,000 and 3,000,000



Source: *ESSENCIS, 2004*

Finally, it should be remembered that the adoption of the different technologies or events assume the same hypotheses as posited in the Reference Scenario.

3.2.8. *Uncertainties (MSW)*

Regardless of the uncertainties that could arise from the life expectancy of the CH_4 generation process (*k*), overall uncertainty regarding GHG emission estimates in this study of MSW is of the order of 41 percent. The set of uncertainties considered in this report with regard to each of the variables contained in the IPCC (2000) method is listed in Table 5 below.

5 Fossil waste comprises different types plastic, foams, polythene, automotive parts, rubber, candles and paraffin.

Table 5 - Estimate uncertainties in the MSW sector

Estimates of the uncertainties associated with *default* parameters in the FOD method for emissions of CH_4 in the LDRSM	
Data on emissions and emission factors	Uncertainties
Total of municipal solid waste (MSW_T) and fraction of the MSW sent to LDRSM (MSW_F)	Specific to each municipality: >±10% (<-10%, >+10%. The absolute value of the uncertainty interval is over 10%) for municipalities with better quality data. In places with poor quality data uncertainty can be more than double. Employed in this estimate = 10%
Degradable Organic Carbon (DOC)	-50%, +20% In this estimate = 35%
Fraction of degradable organic carbon DOC_f = 0.77	-30%, +0% Employed in this estimate = 15%
Correction factor of the CH_4 (MCF) = 1.0 = 0.4 = 0.6	-10%, +0% -30%, +30% –50%, +60% Employed in this estimate = 5%
Fraction of CH_4 generated in landfills (F) = 0.5	-0%, +20% Employed in this estimate = 10%
Recovered CH_4 (R)	Uncertainty will depend on how the quantity of recovered and flared CH_4 is estimated but uncertainty tends to be relatively minor in comparison with other uncertainties if measured *in situ*. Employed in this estimate = 0%
Oxidation Factor (OX)	OX included in the uncertainty analysis in cases where different from zero data is used for OX. In this case the justification for different from zero data must include uncertainty considerations. Employed in this estimate = 0%
Half life (k) = 0.05	-40%, +300% Employed in this estimate = 0%

3.3. Other mitigation options

In addition to the alternative proposed in the Low Carbon Scenario, other technologies can be employed for mitigating GHG emissions caused by waste treatment such as the reduction of waste generation at source and composting.

3.3.1. Reducing waste generation at source

Reducing waste generation at source is a key consideration in terms of sustainability. This mitigation option is highly desirable and tends to be linked to socio-cultural factors which do not depend exclusively on technical, economic or isolated environmental solutions. Reduction of waste generation at source is the ideal scenario which could be encouraged in parallel with the option identified in the Low Carbon Scenario. Recycling, for example, must be considered in this context as a valuable mitigation option.

3.3.2. *Composting*

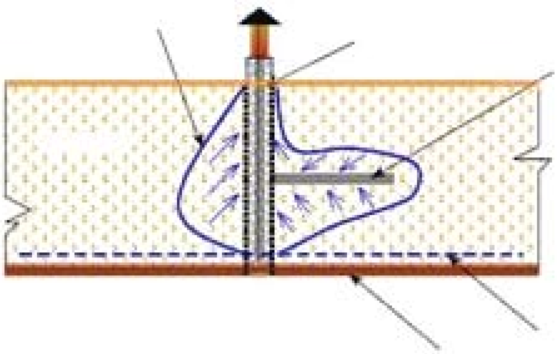
The use of composting is a mitigation alternative which should be considered, mainly in the case of municipalities with populations of under 100,000. This practice calls for the introduction of environmental education initiatives to encourage users to separate waste and for the authorities to undertake selective collection at the lowest possible cost while ensuring maximum quality of the compost produced. Composting is a simple aerobic process which produces no CH_4 emissions. The IPCC (2006) method estimates the N_2O emissions resulting from composting, but the IPCC (2000) method which was used for preparing the scenario contained no emissions estimates. Composting employed in CDM projects is considered to be responsible for a reduction of GHG emissions, given that the MSW which would normally be deposited in landfills and which over the years would emit CH_4 into the atmosphere, is disposed of elsewhere.

3.3.3. *Biogas collection and burning*

The collection and burning of biogas avoids CH_4 emissions. Biogas can be burned in a variety of equipment including heaters, dryers, ovens, boilers, motors, lamps, gas fridges, etc. The process requires a collection system which can be one of two types: forced flow or passive flow exhaustion.

In the *passive* system the biogas is directly flared at the head of the extraction wells with a combustion efficiency of up to 90 percent. The biogas entering these wells is located around the structure and drained off naturally. Figure 22 below illustrates the area of influence (the 'bulb') of the flu within the waste mass. The destruction efficiency of biogas varies from 5 percent to 20 percent of the total gas produced in the landfill, always depending on the type and conditions of the area (whether in operation or not). This method is employed in Brazil.

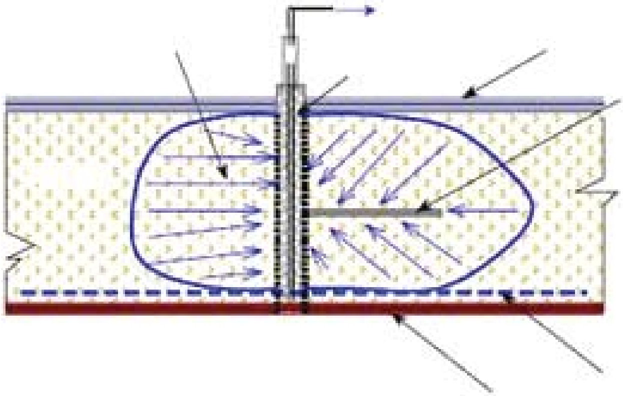
Figure 22 - Example of passive drainage well



Source: ESSENCIS, 2004

In the forced exhaustion system the biogas is collected by a series of extraction blowers installed within the system. The landfill can be covered with PVC or a similar impermeable material to prevent the biogas from escaping from the surface of the landfill. The collection efficiency can be between 70 percent and 80 percent of the total of gas produced in the landfill depending on the type and conditions of the area (in operation or not). Furthermore, burning efficiency is as high as 98/99 percent. Figure 23 below illustrates the 'bulb' of influence when this system is used.

Figure 23 - Example of a forced exhaustion drainage well system



Source: ESSENCIS, 2004

The forced exhaustion collection system requires the following:

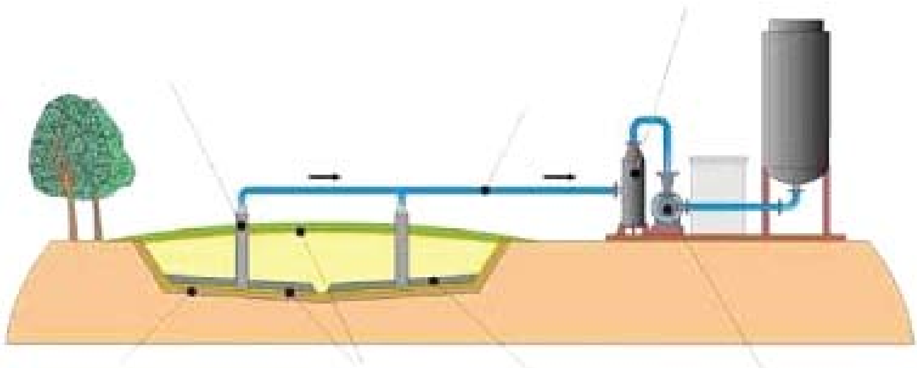
1. A series of vertical extraction wells installed in a regular pattern in the landfill which serve to extract the biogas by forced exhaustion (negative pressure) with extraction blowers;

2. A piping network connected to the top end of the wells for transporting the biogas to the treatment unit;

3. A moisture separator to remove moisture from the biogas before it reaches the extraction blowers and is subsequently flared;

4. The possible installation of some form of impermeable material such as PVC to cover the waste mass.

Figure 24 - Example of a forced exhaustion system (equipment)



3.3.4. *Other benefits*

The Low Carbon Scenario outlined in this report foreshadows a series of economic, environmental, social and health benefits. Other benefits resulting from the correct management of municipal waste could be also simultaneously adopted within the Low Carbon Scenario:

(i) Waste collection services benefit the country's entire population. According to the PMSS II (Programa de Modernização do Setor de Saneamento / *Sanitation Sector* Modernization *Program)* (2003), waste collection is considered to be "universal" when it is provided for all domestic, government, commercial, industrial and service sector premises, etc.

Universally available municipal cleansing services and basic sanitation have a major and direct impact on the health conditions of the population. In the specific case of waste management, appropriate collection and disposal practices aim to control improper disposal of waste in water bodies, streets and elsewhere. These measures should prohibit, for example, the dumping of waste into water catchment facilities or down storm water culverts, all of which can have a deleterious effect on the physical environment.

(ii) Improving the operational aspects of public landfills and ensuring compliance with original system design are basic requirements for ensuring high landfill site operating standards. Good management practices are needed in order to avoid the risk of contaminating the soil and underground water sources with percolated liquids as well as to minimize fire risks from CH_4 spontaneous combustion. The practice of biogas recovery and flaring distinguishes well-operated landfills from those which have not achieved this level of technical quality and efficiency, placing them in a separate class of operation.

(iii) The reduction of waste generation at source forms part of a wider set of anti-pollution measures. The main thrust of this approach is to minimize waste generation rather than to focus on "end-of-line" methods concerned only with the technical operations employed for the final disposal of waste. Measures to reduce waste generation at source include using more efficient packaging compatible with the various alternatives for treating MSW, as well as the adoption of clean technologies in manufacturing processes (CEMPRE, 2000).

According to Kiely (1997), waste reduction at source is the most effective way to minimize waste generation overall and should be regarded as an essential first step. Incentives to encourage source reduction could result in cheaper overall treatment and disposal costs, minimization and control of waste, and avoidance of fines in cases where emission standards fail to comply with the law.

(iv) The reuse and reutilization of waste materials is a cost-effective measure which avoids the need for certain types of waste to be deposited in landfills etc. Many products can be adapted for uses for which they were originally intended (CEMPRE, 2000) and reused. One example is the reuse of glass drink bottles which are collected, correctly washed, refilled with liquids and returned to the consumer market.

On the other hand, recycling is the result of a series of activities involving the collection, separation and processing of waste items to serve as raw material for manufacturing new products (IPT/CEMPRE, 2000).

According to CEMPRE (2000), recycling can be subdivided into internal or external recycling. 'Internal' recycling involves materials being returned to the original manufacturing process, e.g. pre-consumption paper scraps in paper-making factories to be reprocessed in the manufacturing chain rather than being discarded. 'External' recycling involves the transformation of certain discarded materials or products by a given industrial process in order to produce new items which can serve an identical function or some other purpose. Examples of this are PET bottles and aluminum cans which can be recycled to make new cans and even T-shirts.

These three measures share similar environmental benefits given that they can reduce the wastage of natural resources, avoid incineration and avoid occupying valuable space in disposal sites. At the same time, reusing and recycling materials can produce additional economic and social benefits such as the generation of direct and indirect jobs and concomitant opportunities for the social inclusion of poorer people.

(v) Composting is a biological process involving the decomposition of organic material contained in animal or vegetable waste. The process produces organic compost which can be applied to soil, improving it without incurring risks to the environment (IPT/CEMPRE, 2000). Numerous advantages can be obtained from composting such as a reduction in the volume of waste for disposal in sanitary landfills, use of the organic material for agricultural purposes and the elimination of pathogens.

(vi) Thermal treatment with or without energy generation involves 'high' or 'low' temperature processing. The first process, in which temperatures of over 500^0C are reached, is used mainly to destroy or remove organic fractions from the waste. Furthermore, high-temperature thermal treatment produces significant reductions in both waste mass and volume, as well as sterilization. Low-temperature thermal treatment involves temperatures of approximately 100^0C and is used mainly for sterilizing waste.

The mass and organic fraction remains practically unaltered although the volume of waste can be significantly reduced (IPT/CEMPRE, 2000). The main advantages of thermal waste treatment are linked to a significant reduction in both mass and volume of the waste, sterilization and neutralization of hazardous materials and the possibility of using the heat generated for producing energy.

(vii) Generating energy with recovered CH_4 can be done in sanitary landfills or in wastewater treatment plants. Anaerobic digestion of the organic material contained in waste and effluents takes place in these two places. Biogas, given its high concentration of CH_4, can potentially be used as a fuel for power-generating purposes.

CH_4 possesses the potential to negatively impact the environment and affect global climate change given that it is 24 times more noxious than carbon dioxide gas. Thus flaring biogas for energy purposes is better than discharging it in its raw state into the atmosphere, and it can also produce significant economic benefits, as waste facility operators can produce energy for on-site consumption or sell excess gas to third parties.

3.4. Low Carbon Scenario - Solid Waste

While the waste sector Low Carbon Scenario presented in this report refers to one particular technical option - the collection and burning of CH_4, other practices can and should be implemented in the management of MSW, e.g. reduction of waste generation at source, selective collection, recycling, reuse, composting, universalization of waste services or thermal destruction of waste.

The Low Carbon Scenario addresses CH_4 burning on landfill sites. However, it is not recommended to rule out other waste management practices. Under Item 3.2.7 above the contribution to a Low Carbon Scenario by certain other technologies was considered. It is hoped that in practice various alternatives, with different impacts on GHG emissions, can be applied simultaneously.

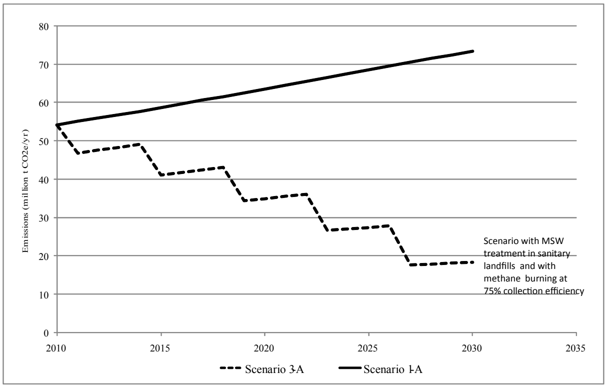
GHG emissions caused by waste incineration are estimated in Item 3.2.7, Other Technologies and Events. Meanwhile, burning fossil waste, if applied indiscriminately throughout the country, could involve increased emissions over the short term. Over the next 20 years GHG emissions from this source could be reduced but care needs to be taken since the increased fossil concentration in waste (as can be observed in Figure 14) could actually result in this practice being as disadvantageous in terms of GHG emissions as the current practice defined in the Reference Scenario (see Figure 7).

3.4.1. *Low Carbon Scenario for the MSW sector*

Burning CH_4 is a practice which has only begun to be followed in Brazil since the entry into force of the Kyoto Protocol. Previously CH_4 was not burnt in landfills in Brazil. As of April 2009 a total of 30 CDM projects involving this method were being addressed in the CIMGC. All the other items in the Reference Scenario are maintained, with the exception of CH_4 destruction at 75 percent landfill collection capacity. This guideline is currently applied to the CDM projects but has yet to be confirmed in Brazilian publications.

Figure 25 below indicates that GHG emissions could be reduced over the next 20 years by 75 percent of the total verified (without this practice) in the Reference Scenario. Over the same period the Reference Scenario, emissions tend to increase in line with population growth and the other features defined in Item 3.2 of this Scenario. In the Low Carbon Scenario GHG emissions reduce from 73 Mt CO_2e to 18 Mt CO_2e in 2030, through the possible application of this burning method in all landfills throughout Brazil, with or without use of the energy[6] produced by CH_4.

Figure 25 - Scenario 3-A: CH4 burned with 75 percent collection efficiency in landfills



3.4.2. *Consolidation*

The Reference Scenario for the MSW sector considers the situation of Brazil in 2007 as described in IBGE, ABRELPE and Ministries of Cities/Environment literature and raises a number of probable outcomes for the period 2010-2030 which can be interpreted as representing the 2030 Reference Scenario for the waste sector with a fair degree of accuracy.

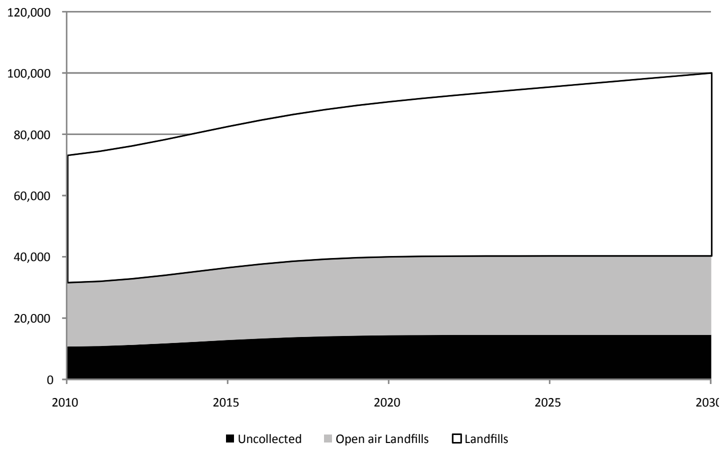
According to ABRELPE (2008) around 15 percent of all waste generated in Brazil is not collected. Notwithstanding the reasons for this, it is considered that during the period up to 2030 this percentage will remain constant - as shown in the Reference Scenario at Figure 26 below.

6 1GW is equivalent to burning .0026 Mt CH_4 or .055 Mt CO_2e.

Also according to ABRELPE (2008), 38.6 percent of the solid waste collected in 2007 ended up in sanitary landfills while 31.8 percent was dispatched to controlled landfills and 29.6 percent to garbage dumps (*lixões*). From 2005 onwards promising measures taken by the Federal Government indicate a genuine and growing concern with the country´s waste situation and with proposals to improve operating conditions in the landfills, mainly in those serving cities with populations of over 50,000. Thus the Reference Scenario considers that between 2010 and 2030 all cities with populations of over 200,000 will possess sanitary landfills (see Table 3). On the other hand, it is reckoned that cities with a population of under 200,000 will not be served by sanitary landfills. The Reference Scenario therefore assumes that the solid waste generated in smaller municipalities with under 200,000 inhabitants will be disposed of in ordinary garbage dumps throughout the entire 2010 through 2030 period.

According to IBGE (2000) the total amount of waste incinerated and composted is under 1 percent of the total of municipal solid waste collected (i.e. insignificant). In the same way, as can be observed in Figure 26, the waste sector Reference Scenario uses an identical percentage figure for incineration and composting and assumes that this will remain unaltered between 2010 and 2030.

Figure 26 - Reference Scenario: MSW services provision

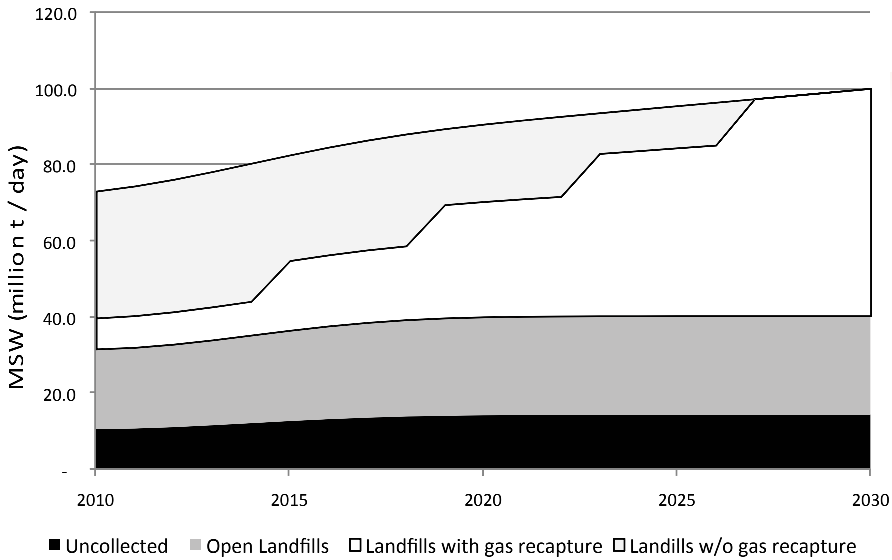


The waste sector Low Carbon Scenario maintains all the hypotheses adopted in the Reference Scenario, with the exception of the practice of collecting and burning CH_4 in sanitary landfills - an increasingly common practice which, it is estimated, will be employed in 100 percent of the sanitary landfills in Brazil by the year 2030. It was deemed that this increase will occur in linear fashion, commencing at 0 percent in 2010 and finishing at 100 percent in 2030.

The Low Carbon Scenario in no way disregards other technologies for reducing emissions such as efforts to introduce environmental education programs aimed at reducing waste generation, recycling and reuse at source, and composting and technologies that promote the use of more environmentally friendly products.

A reality in the major Metropolitan Regions is the decreasing availability of sites for installing new landfills. Disposal of MSW in public landfills is increasingly restricted by environmental licensing and stricter controls over the operation of the existing sites. In this regard, some public health specialists believe that the adoption of capture and burning of CH_4 in the largest cities is inevitable over the next few years. Figure 27 (Low Carbon Scenario) does not cover this technique but aims to gauge the impacts of the adoption of CH_4 burning. Item 3.2.7 covers other technologies that could possibly be used.

Figure 27 - Low Carbon Scenario: MSW services provision



Some idea of the percentage distribution of the sanitation services in the MSW sector in the Reference and Low Carbon Scenarios can be gathered from Figures 28 and 29. Small variations can be seen in the quantities of MSW for disposal in landfills. These variations are caused by the parallel growth of the population, MSW generation, replacement of garbage dumps by landfills and the quantities of waste that are not collected (estimated on the basis of the CETESB model).

Figure 28 - Reference Scenario: Percentage distribution of MSW treatment services

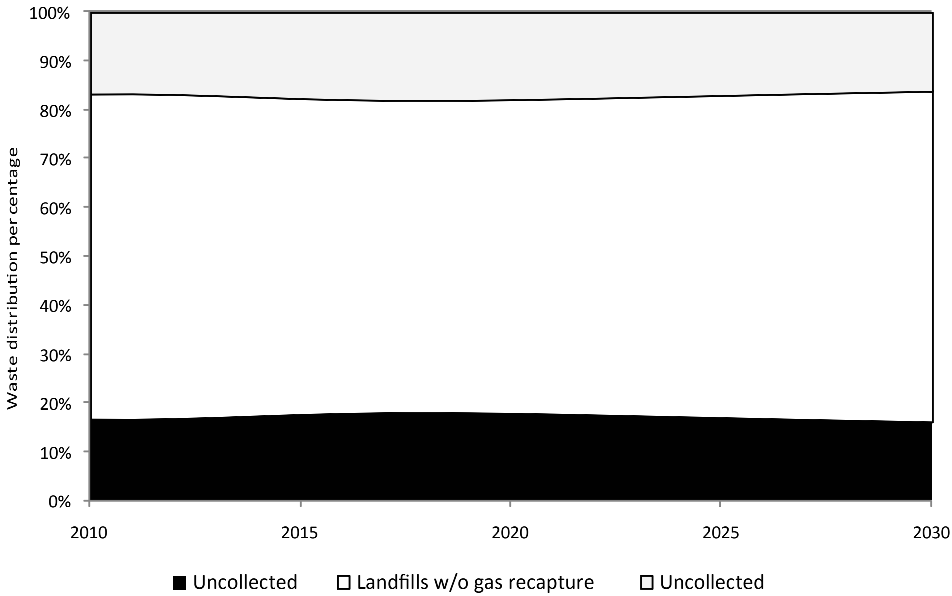
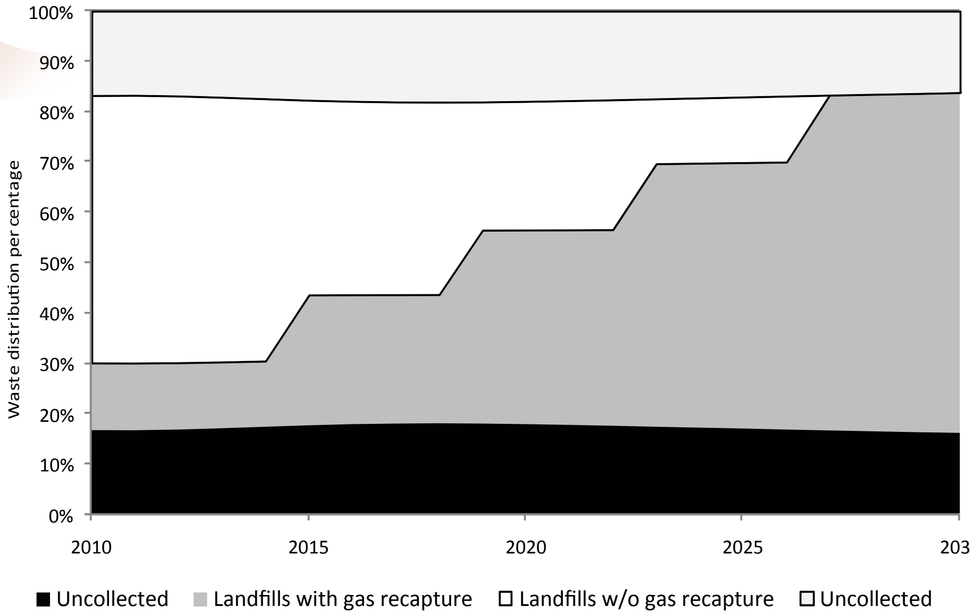


Figure 29 reaffirms the pattern adopted in the Reference Scenario (Figure 28). The difference between the two situations is in the capture and destruction of CH_4 in the landfills, which in year 2030 will possess 100 percent collection and burning systems.

Figure 29 - Low Carbon Scenario: Percentage distribution of MSW treatment services



3.4.3. *Results*

The results of the Low Carbon Scenario for the MSW sector are presented in Figure 30.The number of systems for capturing and burning CH_4 increases, resulting in emission reductions over five year segments. This means that in 2030, 100 percent of all landfills would possess CH_4 capture and destruction systems and the total emissions in the waste sector Reference Scenario would be reduced by 75 percent. Figures 31 and 32 compare the emissions produced in each municipality in the Reference Scenario and the Low Carbon Scenario.

Figure 30 - Low Carbon Scenario 2010-2030

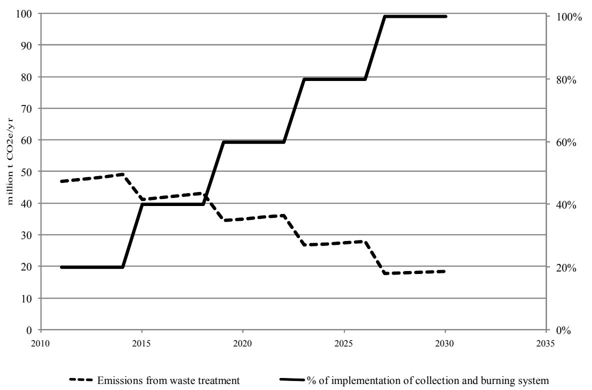
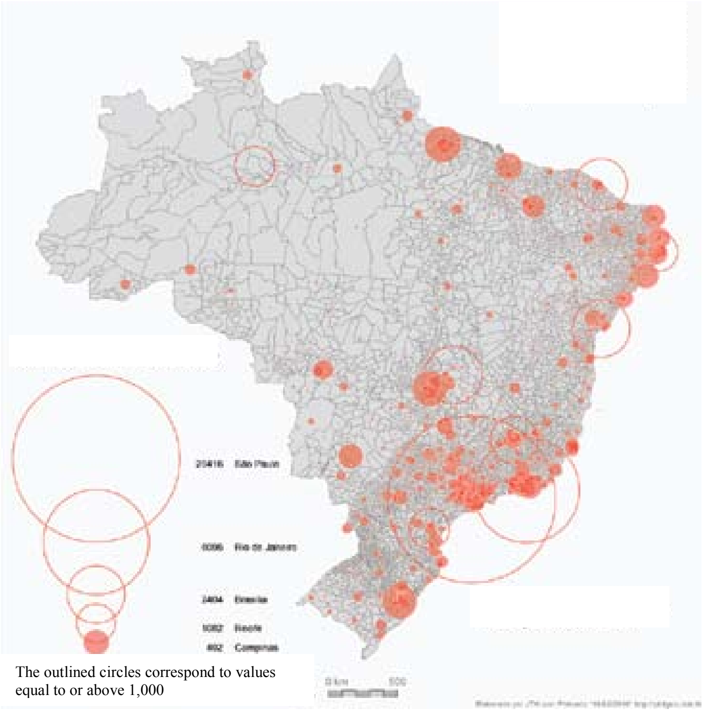
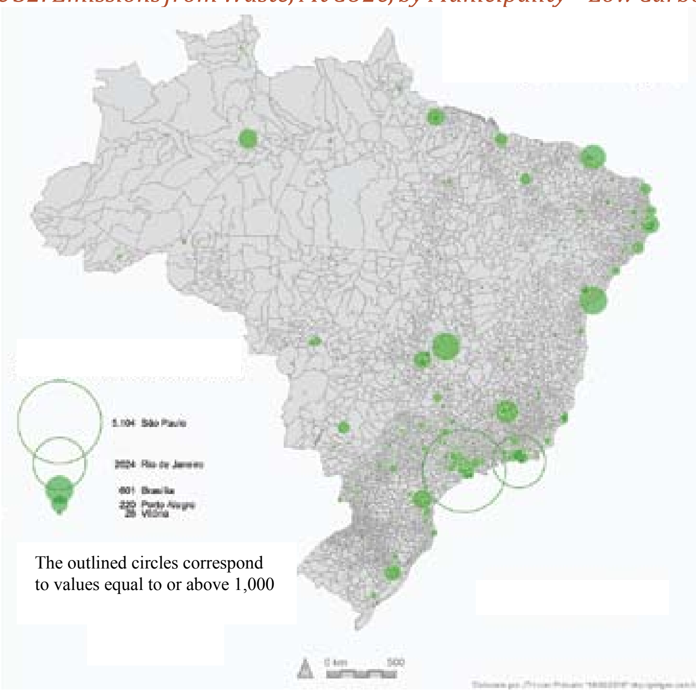


Figure 31: Emission from Waste Mt CO2e, by Municipality – Reference Scenario 2030



Source: CETESB, World Bank Brazil Low Carbon Case Study

Figure 32: Emissions from Waste, Mt CO2e, by Municipality – Low Carbon 2030



Source: CETESB, World Bank Brazil Low Carbon Case Study

The avoided emissions in the Low Carbon Scenario (zero in 2010) increase to 18GtCO_2e in 2015, 29GtCO_2e in 2020, 41GtCO_2e in 2025 and 55GtCO_2e in 2030, effectively corresponding to 75 percent of the landfill emissions indicated in the Reference Scenario.

Table 6 - Low Carbon Scenario: Avoided MSW emissions

Year	Emissions avoided with respect to the Reference Scenario or 1-A (1000tCO_2e)
2010	0
2015	17,620
2020	28,633
2025	41,166
2030	55,105

3.4.4. *Barriers and proposed solutions*

The principal barriers and preventive/corrective initiatives for overcoming them in the environmental sanitation sector for the Low Carbon Scenario are summarized in Table 7 below. The barriers include a range of problems, from the technical and operational constraints experienced by municipalities in the public landfills to major problems caused by the shortage of sites for building new landfills requiring appropriate environmental licensing. The following table sets out a number of preventive, corrective and governances aspects intended to provide guidance for the authorities and other interested parties.

Table 7 - Barriers and mitigation actions related to sanitary landfills

Mitigation actions	Preventive	Corrective	Governance
Technical-environmental barriers			
Capacity Building	Municipalities lack staff and technical skills calling for regional technical-operational support programs.	Repair and environmental recovery of inadequate active MSW disposal sites.	Environmental licensing regularization of active sanitary landfills to bring them fully up to standard.
Availability of environmentally suitable sites	Socio-environmental analysis of sitesselected for waste treatment and disposal.	To encourage the use of a range of techniques (e.g. aerobic composting) in order to treat the organic fraction present in waste.	Reduction and reutilization of waste through separation and selective collection, particularly of the fossil components of waste.
Application of techniques for capturing, burning, recovering and/or using CH_4 for energy purposes	Exchange of experiences between specialized bodies operating similar systems (private local firms, international companies, government bodies, NGOs etc).	Constructing efficient and effective systems with a view to ensuring economic viability and environmental sustainability .	Ensuring compliance with technical norms by environmental bodies and agencies responsible for executing and operating systems in accordance with environmental licensing procedures.
Economic-legal			

Mitigation actions	Preventive	Corrective	Governance
Shortage of investments and funding	Upgrading and procurement of weight calibration/verification systems) and gravimetric characterization of waste.	Substantial and systematic increase in investment over the next 20 years.	Control and supervision of the acquisition and application of financial resources for government plans and programs.
Legal mechanisms for facilitating taxation and charging	Proposal to introduce new measuring and tracking mechanism for quantifying *per capita* waste generation.	To alter the taxing and charging mechanism in respect of waste collection and treatment services.	Integration of the institutional development mechanisms of government sectors concerned with (i) sanitation, environment, water resources and (ii) energy and climate change questions.
Socio-cultural			
	Promotion of ecologically aware consumption, selective collection and reverse logistics in the context of the waste lifecycle generation stream.	Substantial upscaling of selective waste collection through systematic forging of partnership arrangements with cooperatives and NGOs over the next 20 years.	Introduction of tax-exempt mechanisms for the entire lifecycle chaing of selective collection services and reverse logistics, particularly regarding fossil-related waste components.

Table 8 below lists the various barriers and possible preventive, corrective and mitigation actions that could be taken with regard to the potential installation of incineration technology in the country's largest Metropolitan Regions.

Table 8 - Barriers and mitigation actions related to incineration

Mitigation actions	Preventive	Corrective	Governance
Technical-environ-mental barriers			
i. Lack of technical know-how	Opinion formers and sector specialists still lack technical know-how and familiarity with the environmental spin-offs of incinerator operating systems.	Knowledge and capacity build-ing for agents and stakeholders in the application and operation of the relevant incineration systems, paying particular at-tention to the adverse effects on environmental and public health of atmospheric emissions carry-ing possibly toxic substances.	Environmental and licens-ing agencies to pay close attention to technical as-pects of incineration and to analyze prospects for its sustainability in MRs and other large cities.
Economic-legal			

Mitigation actions	Preventive	Corrective	Governance
ii. Substantial investment costs	Feasibility studies for waste treatment employing incineration can only be justified in urban areas with populations of over 3 million.	Proposed installation of high technology devices in incineration systems, introducing highly efficient systems to control and mitigate gases and atmospheric effluents.	Expand long-term planning and project development capacity in municipalities. Expand both public and private sector capacities/ working knowledge of existing legal structures, regulations and procedures required for access to available financing resources (i.e. within appropriate stipulated timeframes, etc.)
iii. Legal mechanisms for facilitating taxation and charging	Proposal to introduce a new measuring and tracking mechanism for quantifying per capita waste generation.	Alteration of the taxation and charging system for waste collection and treatment services.	Incentives to be provided for institutional involvement in shared management based on concession systems and/or PPPs with contracts of over 30 years.
Socio-cultural			
	Promotion of ecologically aware consumption, selective collection and reverse logistics in the context of the waste generation stream.	Substantial upscaling of selective waste collection through systematic forging of partnership arrangements with cooperatives and NGOs over the next 20 years.	Introduction of mechanisms designed to exempt from taxation the entire productive chain utilizing selective collection services and reverse logistics , particularly in the fossil-related waste components.

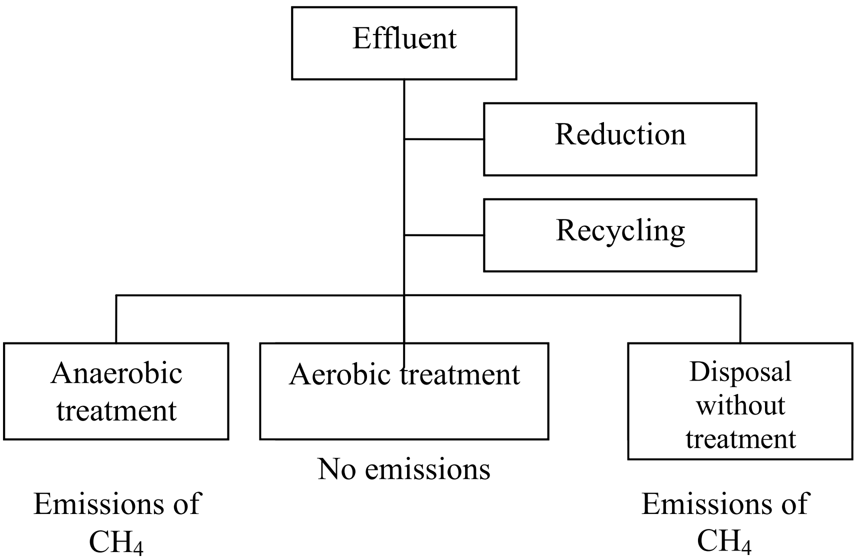
4. Sewage and effluent treatment

The technical alternatives for treating effluents addressed in this section are, similarly to the solid waste emission treatment scenario, only some of the many effluent treatments available in the literature. We describe only those technologies for which the IPCC (2000 and 2006) methods contain data and/or guidance for calculating GHG emissions, where *default* existence is verified (and therefore pre-established emissions factors for each type of technology of effluent treatment).

The model developed for defining the quantities of GHG that can be mitigated and for calculating the additional resources needed for a successful Low Carbon Scenario is described below. The IPCC (2000) method is employed for estimating emissions. The modes of treating and disposing of gas-producing waste and effluents are identified in Item 4.1.

Wastewaters are divided into domestic sewage and industrial effluents. The model also considers the sources of GHG emissions caused by effluent treatment (that can also be differentiated by type of treatment and type of greenhouse gas), as illustrated in the following figure.

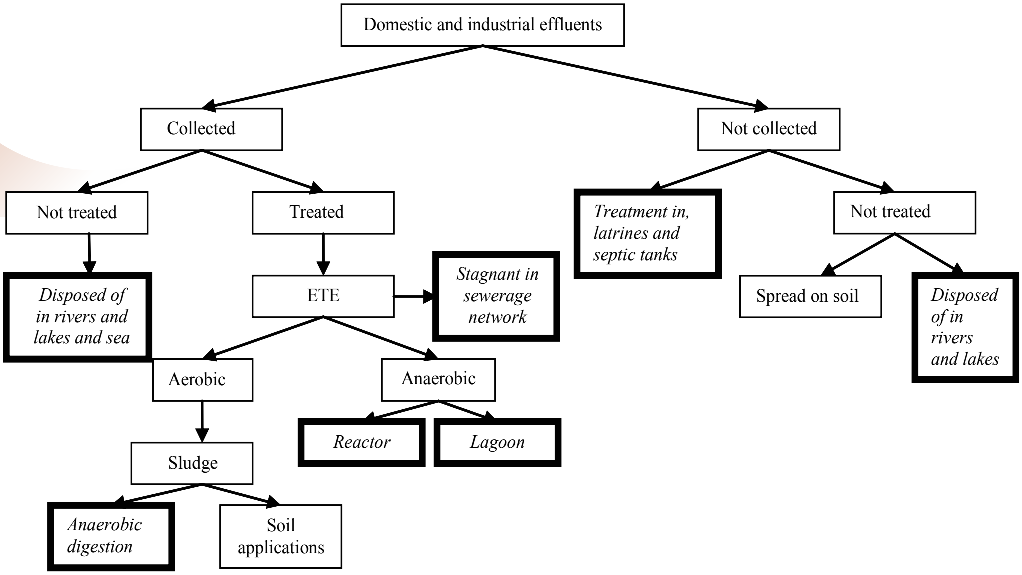
Figure 33 - Sources of GHG emissions caused by effluent treatment



4.1. Treatment modes

The types of anaerobic treatment of effluents proposed by the IPCC (2000) are listed in Figure 34.

Figure 34 - Sources of sewage and effluents, treatment systems and potential CH4 emissions



Note: The italicized text in bold squares indicates a possible source of CH_4 emissions
Source: IPCC, 2000

4.1.1. *Anaerobic lagoons*

The anaerobic lagoon is an alternative form of waste treatment where the existence of stringent anaerobic respiration conditions is essential. This system has been used widely as a primary treatment for predominantly organic sewage and high BOD industrial wastewaters such as those originating from meat, dairy, beverages, paper and cellulose.

Anaerobic lagoons are usually deep (over 2m) and utilized together with aerobic systems such as 'optional lagoons' (the Australian system) or biological filters and activated sludges. Detention time varies between three to six days and the volumetric metric load between 0.1 and 0.3 kgBOD/m^3.day (VON SPERLING, 1998).

4.1.2. *Anaerobic digesters*

Anaerobic sludge digesters are used principally for stabilizing primary and secondary sludges generated by sewage treatment and for treating industrial effluents with a high concentration of suspended solids. The digesters are usually constructed in reinforced concrete in the form of covered circular tanks with diameters varying from 6m to 38m and with depths of between 7m and 14m depending on the existence of mixing equipment and the number of stages. Three main types of digesters are common: (i) low-rate anaerobic digester; (ii) single-phase high-rate anaerobic digester; and (iii) two-phase high-rate anaerobic digester (CHERNICHARO, 2000).

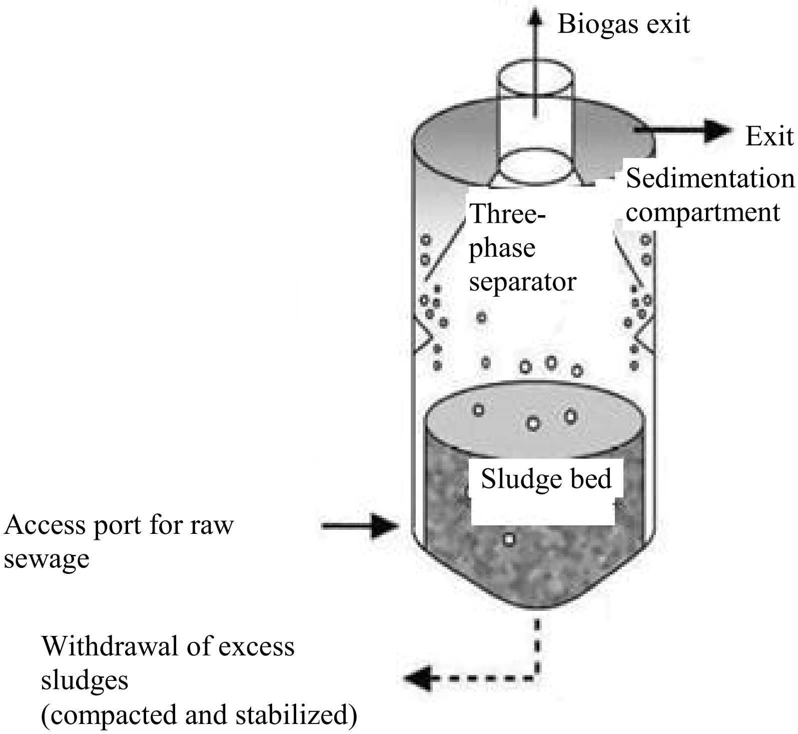
4.1.3. *Anaerobic reactors*

Anaerobic reactors are used for the primary treatment of specific, predominantly organic sewage and industrial effluents with high levels of BOD from products such as meat, milk, beverages, paper, and cellulose.

A number of different types of anaerobic reactors exist of which the most commonly used are of the fixed (anaerobic filters), rotary (anaerobic bio disc), expanded or fluidized bed type. The fluidized bed anaerobic reactor (FBR) is an anaerobic treatment process involving bacterial adhesion and growth on solid surfaces and the creation of a uniform biofilm around each particle or support material, with high volumetric loads of between 20 and 30 kgDQO/m^3.

The use of Upflow Anaerobic Sludge Blanket Reactors (UASB) is currently widespread. The process consists of an ascending hydraulic flow of sewage passed through a blanket of dense sludge, to be degraded by intense and dispersed bacterial activity. Settlement of the organic material occurs in the reaction zones (bed and sludge blanket) with mixing induced by the ascending flow of sludge and gas bubbles. The sludge enters the system at the bottom and the effluent is discharged through an internal decanter located at the top end of the reactor. A device for separating gases and solids located beneath the decanter ensures the correct conditions for the sedimentation of particles which become detached from the sludge blanket, enabling these to return to the digestion chamber instead of being expelled by the system. As can be seen from Figure 35, biogas is generated by the system.

Figure 35 - Upflow Anaerobic Sludge Blanket Reactor (UASB)



Source: Chernicharo, 2000

4.2. *Reference Scenario - sewage and effluent treatment*

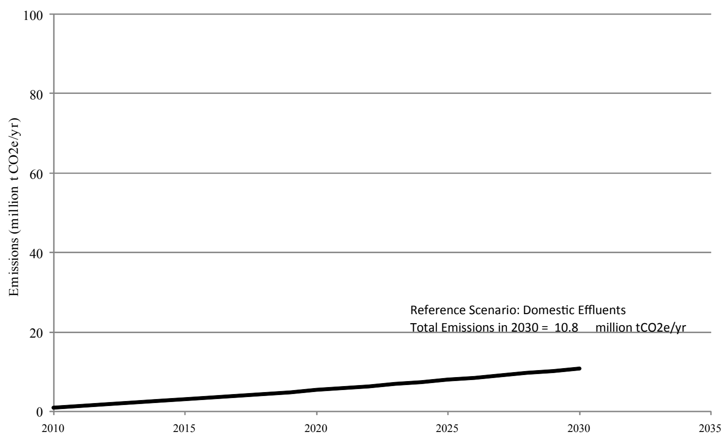
The Reference Scenario for the treatment of sewage and effluents was estimated taking into account the same considerations and assumptions regarding population growth mentioned under Item 3.2.1.

The Reference Scenarios for the sewage and effluents sectors can be described as follows: The generation of organic load in sewage produced by human beings is unlikely to vary as a result of income or regional variations. In Brazil's case, the variables applied to this process are (i) the collection rate, (ii) the type of technology employed to treat collected sewage, and (iii) the employment (or not) of facilities for containing and destroying the CH_4 generated by anaerobic processes. The generation of organic load in effluents generated by industrial processes varies, although it is difficult to define a particular model that can represent this variation over time. Each case possesses peculiarities and it is not possible, given the level of information currently available, to define a mathematical model to simulate the technological variations and their potential for generating organic load or CH_4 by the treatment process accompanying the manufacturing process. Scenarios 1-B and 1-C (see Figures 36 and 37) represent the Reference Scenarios for the domestic sewage and industrial effluents sectors respectively.

4.2.1. *Domestic sewage*

The Reference Scenario shown in Figure 36 below reflects the deployment of the Federal Government´s basic sanitation plans for the universalization of sewage collection and treatment services up to year 2030. Collection figures for 2010 are in the region of 50 percent, while sewage treatment does not exceed 10 percent of the amount actually collected (PNSB, 2000). These figures, taken together with forecast population growth, form the basis of the Reference Scenario in the study. Note that the expansion of the sewage treatment services has been conceived on the basis of technical solutions employing a combination of activated sludge systems and anaerobic reactors for treating sewage. This means that 33 percent of the organic load must be removed through an aerobic process and the remaining 67 percent by the anaerobic process in a sludge reactor. The sludges from both processes, once stabilized, are then delivered to sanitary landfills for final disposal. The emissions in this Reference Scenario can thus be estimated.

Figure 36 - Scenario 1-B or Reference Scenario for Domestic Sewage

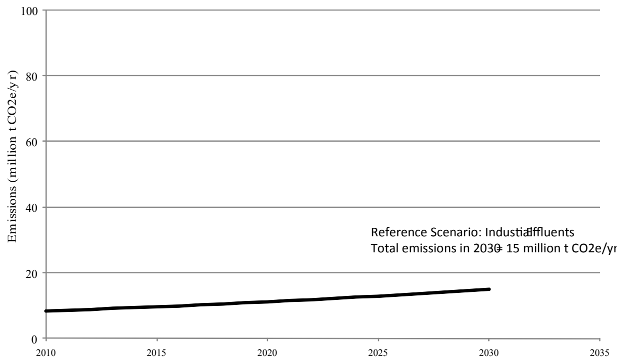


4.2.2. *Industrial effluents*

In the treatment of industrial effluents the organic load varies considerably depending on the type of activity pursued by a given firm. Food and beverage manufacturers have been burning CH_4 from biogas through anaerobic treatment facilities since the 1980s.

The Reference Scenario shown in Figure 37 reflects the assumption of the continuation of generation and burning of CH_4 from industrial effluents, with anaerobic treatment indices of around 20 percent (PNSB, 2000).

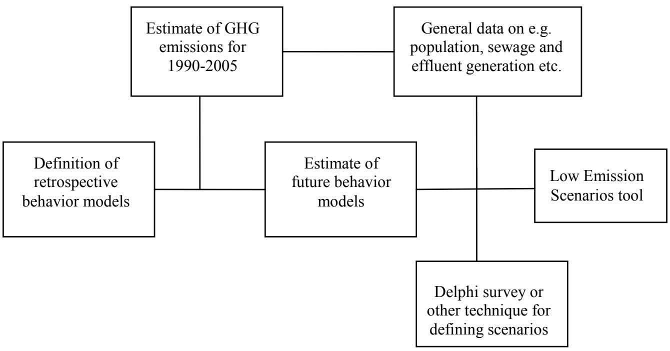
Figure 37 - Scenario 1-C or Reference Scenario for Industrial Effluents



4.2.3. *Calculation Methods*

The elaboration of the 2030 Low Carbon Emissions Scenario for the treatment of effluents was defined by utilizing the international inventory method of the IPCC (2000) and the method described as follows. This second method mentioned above was adapted and applied as described below.

Figure 38 - General strategy for elaborating the 2030 Scenario regarding GHG emissions caused by effluent treatment



As can be observed from the above, estimating the 2030 scenario begins with a definition of relevant behavior evolution models for the study of the recent past. These models are regressions, for the most part linear, of the *per capita* evolution of organic load generation, effluent treatment technologies etc.

Once these models are defined, the possible alternatives of evolution are considered and analyzed with respect to the possibility of occurrence in the study's scenario.

4.2.4. Estimate of GHG emissions from sewage and effluent treatment

The method employed for estimating GHG emissions caused by sewage and effluent treatment in the 2030 Scenario was the same as that employed for elaborating the Reference Report (included in the National Communication) on GHG emissions in the waste sector. The IPCC (2000) method was used to obtain this estimate.

The scenario includes the estimate of CH_4 emissions produced by anaerobic degradation of organic loads that occurs in sewage treatment stations (ETEs) using anaerobic reactor and lagoon processes or in plants employing aerobic/anaerobic processes such as anaerobic sludge digesters. No estimate was done of the emissions generated by anaerobic degradation of sea, river and lake organic loads or those produced by domestic/localized treatment processes such as latrines and septic tanks.

The models employed for estimating GHG emissions, adopted from the IPCC (2000) and employed for this scenario are described below.

Equation 10 - Estimate of CH4 emissions from anaerobic treatment of sewage and effluents

$$Emissions = TOW \, . \, EF - R$$

where:

Emissions	= *Quantity of* CH_4 *generated per year*	[$GgCH_4$/yr]
TOW	= *Total sewage or organic effluent*	[kgBOD/ yr]
TOW_{dom}	= *Total organic domestic sewage*	[kgBOD/ yr]
TOW_{ind}	= *Total organic industrial effluent*	[kgBOD/ yr]

Equation 11 - Estimate of total organic sewage and effluent

$$TOW_{dom} = P.D_{dom}$$

where:

P	= *Population*[5]	[1.000 persons]
D_{dom}	= *Degradable organic component of domestic sewage*	[kgBOD/1,000persons yr]

Equation 12 - Estimate of total organic sewage and effluent

$$TOW_{ind} = Prod.D_{ind}$$

Prod	= *Industrial production*	[product/yr]
D_{ind}	= *Degradable organic component of industrial effluent*	[kgBOD/product/yr] or [kgDQO/product]

Equation 13 - Estimate of emission factor for sewage and effluents

$$EF = B_0 . \text{Weighted mean of the MCF}$$

where:

B_0	= Maximum capacity of production of CH_4	[$kgCH_4/kgBOD$] or [$kgCH_4/kgDQO$]

Equation 14 - Weighted mean of MCF

$$\text{Weighted mean of the } MCF_i = \sum_x (WS_{i,x} . MCF_x)$$

where:

Weighted mean of the MCF	= Fraction of BOD degradable anaerobically	[dimensionless]
$WS_{i,x}$	= Fraction of type "i" sewage or effluent treated using the "x" system	[dimensionless]
MCF_x	= Conversion factor of CH_4 of the "x" system treating "i" sewage or effluent	[dimensionless]

R	= Recovery of CH_4	[$GgCH_4/yr$]

4.2.5. Results

The Reference Scenario for emissions caused by domestic and industrial effluent treatment is represented by Figure 39 below. The total emissions increase from just over 9,174,000 tCO_2e in 2010 to over 25,792,000 tCO_2e in 2030.

Figure 39 - Reference Scenario for Domestic and Industrial Effluent Emissions

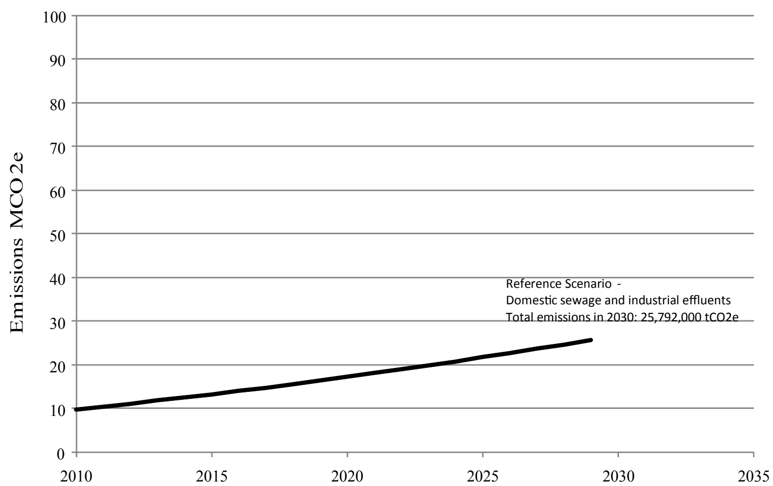


Table 9 below summarizes the evolution of emissions between 2010 and 2030. The emissions virtually triple during this period.

Table 9 - Reference Scenario: Emissions due to sewage treatment

Year	Emissions from domestic sewage and industrial effluents treatment (1,000 tCO_2e)
2010	9,174
2015	12,612
2020	12,505
2025	20,886
2030	25,792

4.2.6. Uncertainties related to the estimates for the domestic sewage sector

Uncertainty regarding the estimates of GHG emissions in the domestic sewage sector is on the order of 42 percent and in the effluent sector around 63 percent. Both are defined by the IPCC (2000) method according to the *default* data presented in Tables 10 and 11.

Table 10 - Estimate uncertainties in the domestic sewage sector

Estimates of the uncertainties linked to *defaults* and parameters for the emission of CH_4 in domestic sewage treatment systems.	
Emissions data and factors	Uncertainties
Human population	± 5% Used in this estimate: 5%
DQO/per capita	±30% Used in this estimate: 30%
Maximum capacity of CH_4 (B_0) production	±30% Used in this estimate: 30%
Fraction treated anaerobically	Uncertainty must be judged by specialists, given that this is a fraction and that uncertainties cannot fall outside an interval of between 0 to 1.

Source: Adapted from IPCC (2000)

Table 11 - Estimate uncertainties in the industrial effluent sector

Estimates of the uncertainties linked to defaults and parameters for the emission of CH_4 in domestic sewage treatment systems.	
Emissions data and factors	Uncertainties
Industrial production	± 25 percent. Specialist appraisal required to confirm the quality of the data source and determine more accurate uncertainty intervals. Used in this estimate: 25 percent
Effluent/productive unit DQO/unit of effluent	This data is relatively uncertain given that the same sector may use different effluent treatment procedures in different countries. The product of the parameters should possess less uncertainty. The uncertainty data can be attributed directly to kg DQO/t of product. -50 percent, 100 percent is suggested. Used in this estimate: 50 percent
Maximum capacity of CH_4 (B_0) production	±30 percent Used in this estimate: 30 percent
Fraction treated anaerobically	The uncertainty must be determined by specialists, given that this is a fraction and that the uncertainties cannot fall outside the interval of 0 to 1.

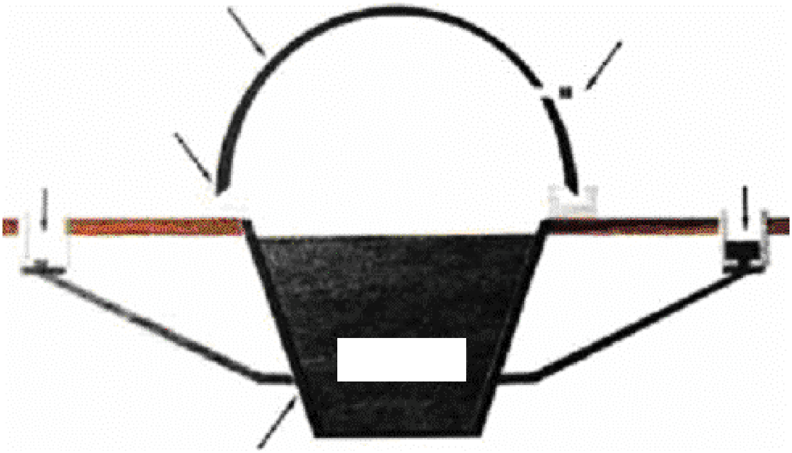
Source: Adapted from IPCC (2000)

4.3. Mitigation options

When using anaerobic lagoons for treating liquid effluents a common practice is to cover the entire system with a PVC or PEAD membrane in order to contain gases and to assist the collection and burning of CH_4. The system has proved to be of low efficiency for capturing biogas (less than 30 percent) and has led to gases escaping during operations. A number of CDM private sector projects in industries with high strength organic load rates have been the subject of validation and registration in the UNFCCC (United Nations Framework Convention on Climate Change).

Figure 40 illustrates an anaerobic lagoon with the biogas collection system covered with a PVC membrane.

Figure 40 - Anaerobic lagoon with biogas collection



Source: ECOINVEST, 2006

Liquid effluent anaerobic reactors, sludge anaerobic digesters, and waste anaerobic digesters require biogas collection plants, normally consisting of the following components:

1. Collection pipes at the head of each anaerobic digestion system
2. Valves to alleviate pressure and vacuum
3. A gas collector for collecting gas from lagoons, digesters and/or reactors and supplying the burner
4. Gas seal pots
5. A sediment separator
6. A flame shut-off valve
7. A control, measuring and regulation unit
8. An open and/or enclosed burner
9. A well-head burner

The pipes that collect the gas at the well head should allow for the installation of a manhole for inspection purposes. The material used in the collectors can be PVC, PP, PAD or metal.

At the biogas exit points in each digestion system a seal pot must be installed in order to allow gas to pass in only one direction, thereby preventing interlinking of the gaseous phases. This device (manufactured from stainless steel) must be installed at the head of the system. In order to eliminate scum,[7] sediments or other materials that can be sucked into the biogas, steps must be taken to install a sediment separator in the principal collector, to include a siphon, drain valve and an instrument for checking levels. This system must be constructed of 100 percent stainless steel.

After passing through the sediment separator, the biogas passes to the combustion area. The collector must be totally aerial and slope towards the separator or sealing pot of the burner. It must not have low points where condensate could accumulate.

The most efficient burner in terms of H2S, NH3, mercaptans, volatile organic compounds and CH_4 is the 'enclosed' type. In this type of burner combustion occurs in a thermically isolated closed chamber and under controlled temperature conditions. By maintaining a constant combustion temperature of over 800°C (by controlling the amount of excess air entering the system) and a residence time of over 0.5 seconds, all the compounds are converted into oxides and water thereby eliminating disagreeable odors. Given the normal destruction efficiency of higher than 99 percent, this type of burner is preferred in CDM projects.

4.3.1. *Other benefits*

The suggested Low Carbon Scenario in the present report is likely to produce economic, environmental, health and social benefits. A number of the benefits related to sewage and effluent management that could be provided by these practices and which are not comprised in this Low Carbon Scenario but which should be adopted simultaneously, are listed below.

i. Sewerage services have a direct impact on health. For example improvements in the various systems can avoid the dissemination of disease-causing insects. Furthermore, using correct treatment systems for sewage and effluent preserves the quality of water sources for public supply.

ii. Operational improvements in the effluent treatment systems involve the development of better techniques ensuring that sewage is treated more safely and efficiently.

iii. Increased effluent generation calls for the construction of new treatment facilities or extensions to the operational capacity of existing facilities, involving significant public and private investments. It is preferable to invest in effluent generation reduction at the source, which can have a positive benefit on the treatment systems (lower operational costs) and the public water supply (better quality water).

iv. Water recycling. According to Mierzwa and Hespanhol (2005), certain activities tolerate water of a non-potable grade or of a lower quality than that used in many industrial processes. In this respect water reuse can be a worthwhile

7 Scum: a layer of grease that forms and floats on the surface of sewage and effluent treatment systems

management practice which can reduce pressure on water resources, together with the adoption of practices to reduce water use at source. The use of treated or untreated effluents for irrigation, industrial or non-potable water purposes is one of the aspects of water and effluent management and can be a useful instrument for preserving natural resources and controlling pollution (MIERZWA and HESPANHOL, 2005).

v. Generating energy from recovered CH_4 can also be applied to effluent treatment systems.

4.4. Low Carbon Scenario - sewage and effluent treatment

The Low Carbon Scenario for the sewage and effluent treatment sector assumes an increase in the scale of collection and anaerobic treatment as systems for collecting and burning CH_4 are gradually introduced. Selection of technologies for treating sewage and effluent is done according to environmental, technical, operational and economic criteria. In addition to anaerobic technology, aerobic processes or a combination of anaerobic/aerobic methods can be employed for sewage and effluent treatment.

It is widely known that biogas from sewage and effluent treatment is only produced by anaerobic processes, given that aerobic processes do not include methanogenic bacteria and therefore do not produce the biogas CH_4.

The use of other technologies (non-anaerobic) has been discarded for the Low Carbon Scenario because they are not responsible for significant greenhouse gases. Moreover they are not considered by the IPCC (2000) method.

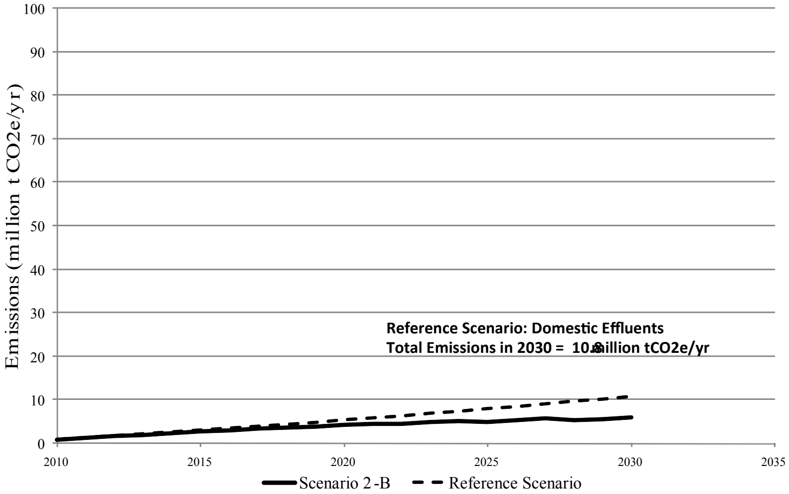
The Reference Scenario for the domestic sewage sector (1-B) has been shown in Figure 36 and the Reference Scenario for the industrial effluent sector (1-C) in Figure 37. The Low Carbon Scenario for the domestic sewage sector (3-B) is shown in Figure 45 and the Low Carbon Scenario for the industrial effluents sector (3-C) can be seen in Figure 47. The Low Carbon Scenarios involve the introduction of anaerobic treatment with the capture and burning of 100 percent of the CH_4 generated, which results in higher quantities of waste treated with total abatement of emissions.

4.4.1. Low Carbon Scenario for domestic sewage

The domestic sewage treatment sector Low Carbon Scenario presupposes that the Reference Scenario assumptions are retained i.e. universal delivery by 2030 of 100 percent domestic sewage collection and treatment services. In addition to subscribing to the Reference Scenario in these terms the Low Carbon Scenario also incorporates systems for capturing and burning the biogas generated as a result.

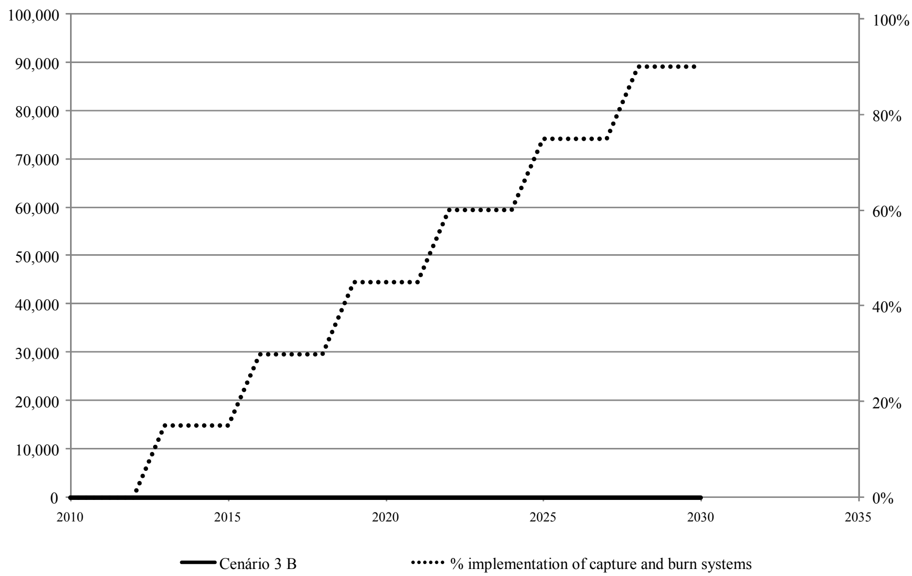
In Scenario 2-B (in Figure 41) the Reference Scenario assumptions are retained. In addition to continuing to subscribe to the Reference Scenario, Scenario 3-B also includes the installation of biogas capture and burning systems for burning around 50 percent of the biogas generated. The burners used in these systems possess a methane burning efficiency of 90 percent.

Figure 41 - Scenario 2-B: 50 percent of domestic sewage collected and treated anaerobically



Scenario 3-B (Low Carbon – Figure 42) mirrors the Reference Scenario, with the universalization of domestic sewage collection and treatment provision, including the installation of systems for collecting and burning biogas at an estimated burning efficiency level of 90 percent in all the sewage treatment systems. Emission reductions will as a result be achieved progressively (as the installations are gradually introduced) from 0 percent in 2010 to 100 percent in 2030. Anaerobic sludge digesters possess a burner which operates at a methane burning efficiency level of 90 percent, which implies a residual emission of 10 percent of the total methane emitted in the Reference Scenario. This constitutes the Low Carbon Scenario for the domestic sewage sector.

Figure 42 - Scenario 3-B: collection and burning of biogas generated in some of the domestic sewage treatment systems from 2010-2030

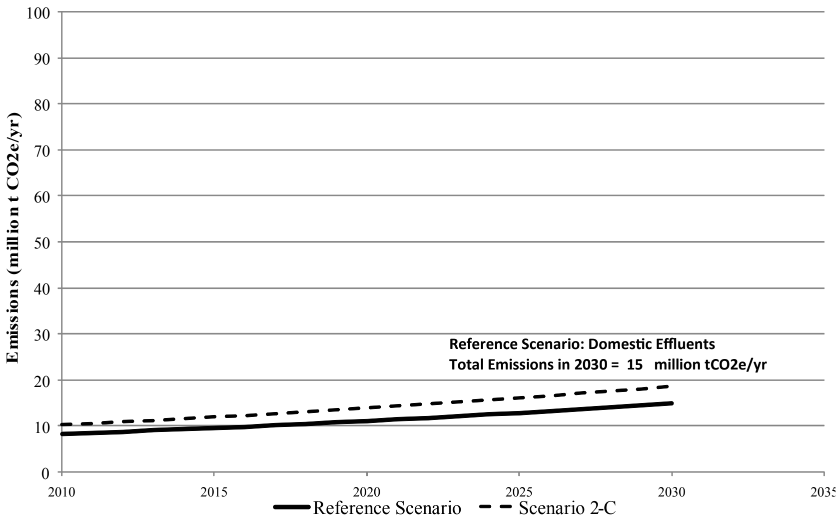


4.4.2. *Low Carbon Scenario for Industrial Effluents*

The industrial effluents treatment sector Low Carbon Scenario presupposes that the Reference Scenario assumptions are retained i.e. growth of industrial production by 3 percent per annum up to year 2030, with 50 percent of industrial effluents treated anaerobically. In addition to subscribing to the Reference Scenario in these terms the Low Carbon Scenario also incorporates systems for capturing and burning around 50 percent of the biogas generated as a result.

In Scenario 2-C (Figure 43) the Reference Scenario assumptions are retained. In addition to continuing to subscribe to the Reference Scenario, Scenario 2-C also includes the installation of biogas capture and burning systems for burning around 50 percent of the biogas generated. The burners used in these systems possess a methane burning efficiency of 90 percent.

Figure 43 - Scenario 2-C: 50 percent of industrial effluents collected and treated anaerobically



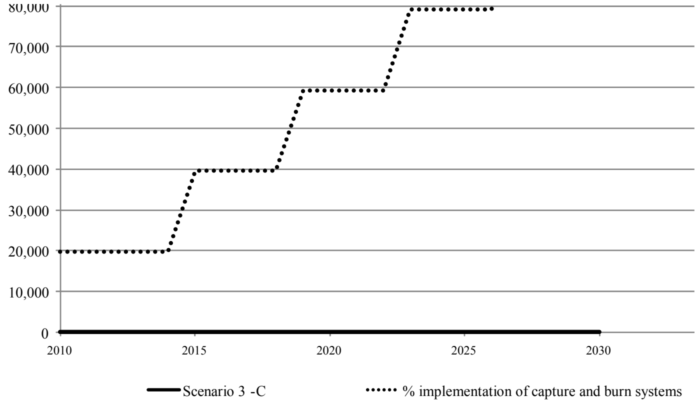
In Scenario 2-C, which can be interpreted for any fraction of treated sewage by the anaerobic process, 100 percent of the CH_4 generated is destroyed.

Scenario 3-C (Figure 44) represents the Low Carbon Scenario of the industrial effluents sector (3-C). This scenario assumes the installation of anaerobic digestion systems with the capture and burning of CH_4. Installation of these systems increases by a factor of 20 percent up to 2014, 40 percent between 2014 and 2018, 60 percent between 2018 and 2022, 80 percent up to 2026, and finally 100 percent by 2030.

In Scenario 3-C the Reference Scenario assumptions are retained. In addition to continuing to subscribe to the Reference Scenario, Scenario 3-C also includes the installation of biogas capture and burning systems for burning around 100 percent of the biogas generated. The burners used in these systems possess a methane burning efficiency of 90 percent.

The first Low Carbon Scenario simulated for the industrial effluents sector suggests a significant increase in CH_4 emissions.

Figure 44 - Scenario 3-C: Burning CH4 generated by treatment of industrial effluents 2010-2030

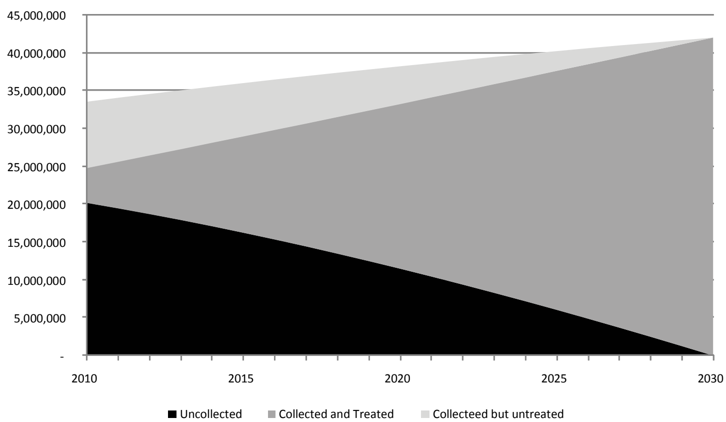


4.4.3. *Consolidation*

The sewage and effluents Reference Scenario takes into account Brazil's situation in 2007 according to information issued by IBGE and the Ministries of Environment and Cities. The Reference Scenario also contains a number of considerations for the period between 2010 and 2030 which are assumed to be the most "probable" and which represent more accurately the 2030 scenario.

According to the IBGE National Basic Sanitation Survey (PNSB) around 60 percent of all sewage is not collected but discharged directly into water bodies or treated in systems such as pits or latrines. While the remaining 40 percent is collected only 14 percent of this is treated aerobically or anaerobically. In accordance with the PLANSAB, the PAC and a series of other guidelines established by the Federal Government at the end of the first decade of the 21st century, the universalization of the the collection and treatment of all urban domestic sewage is assumed to be achieved between 2010 and 2030, implying the collection and treatment of 100 percent of the sewage generated in Brazil´s urban areas. The Low Carbon Scenario adds the capture and burning of methane gas to the assumptions of the Reference Scenario at an efficiency level of 90 percent. Figure 45 represents the Low Carbon Scenario. This is in step with the Reference Scenario except for the amount of methane emitted.

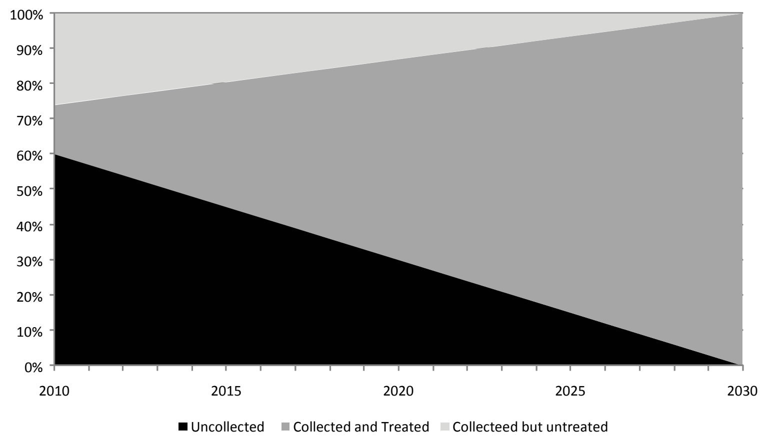
Figure 45 - Low Carbon Scenario: Domestic sewage treatment systems



The sewage and effluents Low Carbon Scenario represented in Figure 46 below maintains all the hypotheses adopted in the Reference Scenario with the exception of the installation in the sewage treatment plants of systems for collecting and burning biogas at an efficiency level of around 90 percent. These installations will be introduced progressively, from 0 percent in 2010 to 100 percent by 2030.

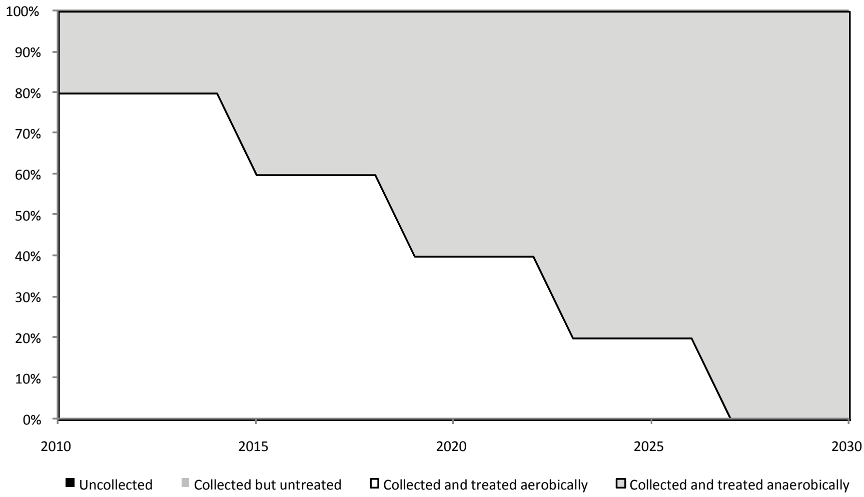
The Low Carbon Scenario does not in any way rule out the other technologies for reducing emissions such as introducing environmental education programs aimed at water reutilization and reduced 'at source' emissions generation.

Figure 46 - Low Carbon Scenario: Percentage distribution of domestic sewage treatment systems



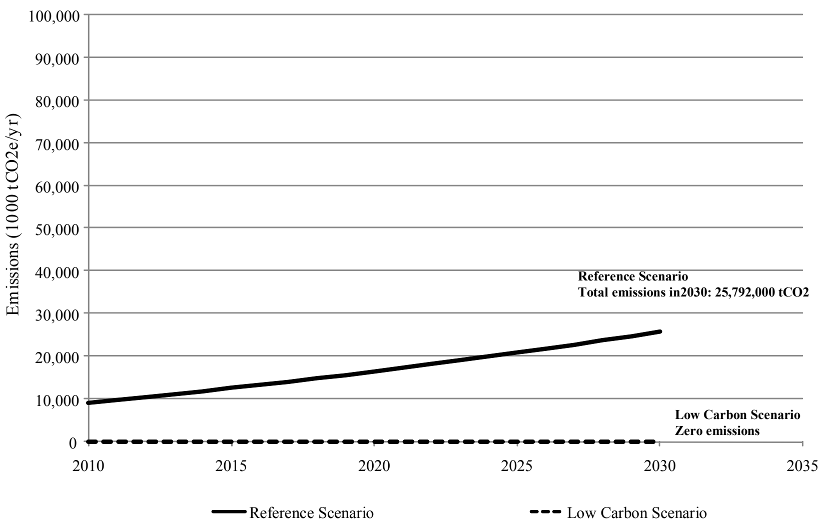
The Low Carbon Scenario for the industrial effluents sector, similarly to the data survey included in the Reference Report of Brazil's GHG emissions from this sector in 1990-2005, does not cover all the country's economic activities. The IPCC (2000) method recommends that three of the main activities that generate organic load should be selected and that a survey of data should be confined to these activities for defining the Brazil´s emissions. Furthermore, it is considered that according to law all effluents that are generated are treated by aerobic or anaerobic processes. While the Reference Scenario is represented by these two processes, incorporating biogas collection and burning, the Low Carbon Scenario only incorporates the expansion of treatment by anaerobic processes together with biogas collection and burning. No increase or reduction of greenhouse gases is involved since, according to CETESB, such methane emissions do not occur at present.

Figure 47 - Low Carbon Scenario: Percentage distribution of industrial effluent treatment systems



The sewage and effluents Reference Scenario is summarized in Figure 48. The increase observed in the emissions of the Reference Scenario simply reflects Brazil's economic and population growth. Introduction of the Low Carbon Scenario results in a reduction of emissions as a result of the anaerobic treatment of domestic sewage and the recovery and burning of CH_4 generated by this practice.

Figure 48 - Low Carbon Scenario: treatment of sewage and effluents



The emissions observed in 2010 of around 7 $MtCO_2e$ could be reduced to zero in 2030 even while taking into account forecasted expanded economic activity and population growth.

4.4.4. *Barriers and proposed solutions*

Table 12 summarizes the main barriers and the preventive, corrective and governance actions aimed at mitigation in the environmental sanitation sector related to the Low Carbon Scenario.

Table 12 - Barriers and mitigation actions related to effluent treatment

Mitigation actions	Preventive	Corrective	Governance
Technical-environmental			
Application of techniques for collecting, burning recovering and/or using CH_4 for energy purposes.	Exchange of experiences between specialized bodies operating similar systems (private local firms, international companies, government bodies, NGOs etc).	Operation of efficient and effective systems with a view to ensuring economic viability and environmental sustainability.	Environmental and licensing agencies to pay close attention to technical aspects of effluent treatment in compliance with standard procedures.
Economic-legal			
Increased investments and financial resources	Application of new approaches to collection, burning, recovery and / or CH_4 energy-producing methods in systems currently involving gas emissions generation.	Substantial and systematic increase in investment over the next 20 years.	Control and supervision in the procurement and application of financial resources earmarked for government plans and programs.
Socio-cultural	Water recycling and use of cleaner technologies with a view to enhancing the supply capacity of water bodies.	Substantial increase in water loss control and rationalization of water use aimed at improved resource sustainability.	Introduction of mechanisms to provide tax incentives to firms and others which employ water recycling techniques and cleaner production methods.

5. Consolidation of Low Carbon Scenario

5.1. Synthesis of Low Carbon Scenario

The Low Carbon Scenario for GHG emissions caused by waste treatment, depicted in Figure 49 is projected on the basis of simply burning CH_4 emissions through the anaerobic treatment of the organic content of municipal waste, domestic sewage, and industrial effluents. If the practice of waste disposal in landfills is maintained, the CO_2 emissions resulting from incineration of the fossil component of municipal waste and the N_2O emissions caused by waste incineration can be regarded as 'avoided'. In Figure 19 (Section 3.2.6) it is possible to gauge the level of N_2O and (mainly) CO_2 emissions produced by municipal waste.

Figure 49 - Low Carbon Scenario: Total emissions from treatment of waste, sewage and effluents

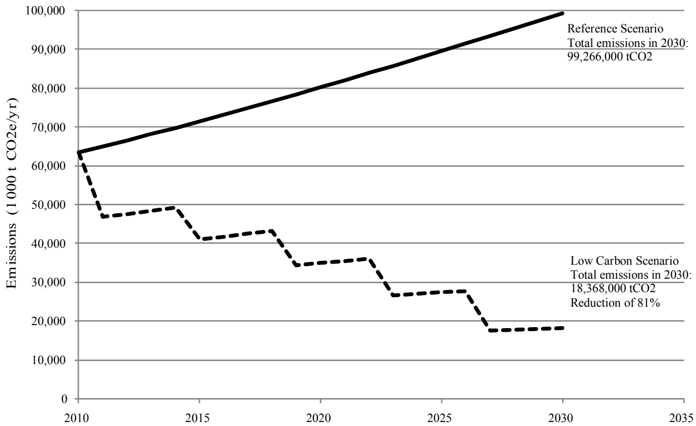


Table 13 - Low Carbon Scenario: Total emissions from waste, sewage and effluent treatment

Year	Total emissions from waste, sewage and effluent treatment	Emissions avoided vis-à-vis Reference Scenario
	($1000tCO_2e$)	
2010	63,798	0
2015	46,894	24,451
2020	39,465	40,670
2025	30,034	59,462
2030	18,368	80,897

According to the data in Table 13 the practice of collecting and burning CH_4 in landfills and ETEs could produce emissions savings in 2030 of around 3400 tCO_2e, equivalent to a 1.5GWe power output.

5.1.1. *Results according to states*

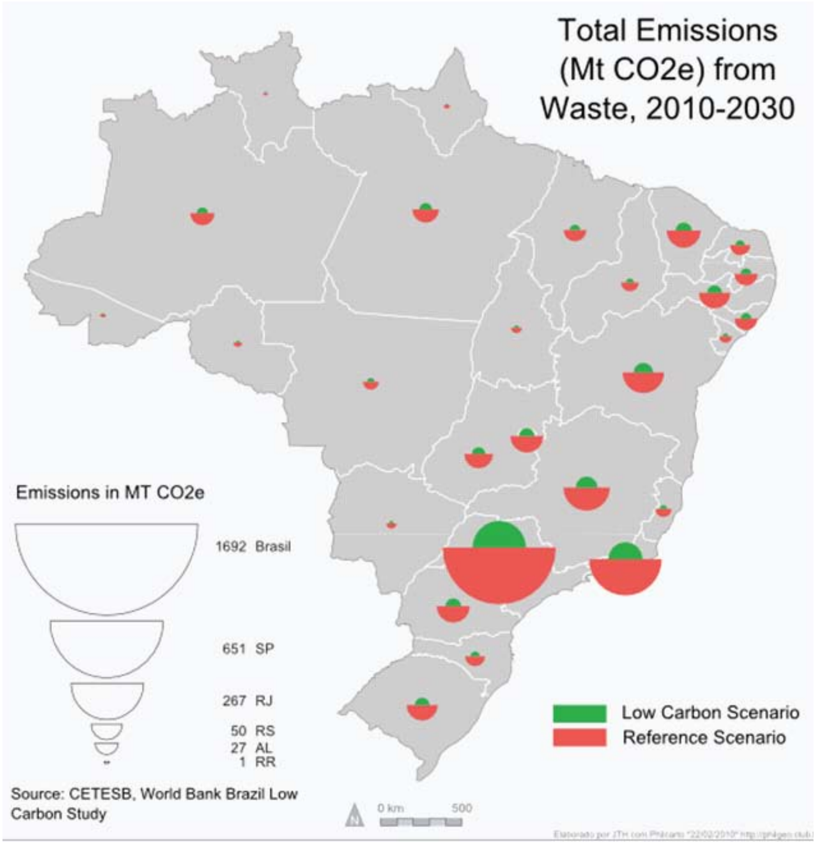
Table 14 summarizes the total GHG emissions, by state, resulting from waste in years 2010 and 2030. In 2010, total emissions of the states in the north region amount to 2,212 tCO_{2e} (4.8 percent), while the total emissions of the combined states of the northeast are 8,010 tCO_{2e} (17.4 percent). The emissions for the center-west are 3,139tCO_{2e} (6.8 percent), for the southeast region 29,255tCO_{2e} (63.5 percent) and for the south region 3,454tCO_{2e} (7.50 percent). The state of São Paulo alone is responsible for 39.5 percent of all Brazil's emissions. The combined emissions of the states of São Paulo, Rio de Janeiro and Minas Gerais account for 62.8 percent of Brazil's total emissions.

Table 14 - Low Carbon Scenario: Emissions from waste, sewage and effluent treatment (by State)

State	Emissions by state		Percentage of Emissions	
	2010	2030	2010	2030
	(1000 t CO_2e)		%	
AC	52	25	0.1%	0.1%
AL	842	299	1.6%	1.6%
AM	986	315	1.8%	1.7%
AP	62	31	0.1%	0.2%
BA	2,484	1,016	4.6%	5.5%
CE	1,716	705	3.2%	3.8%
DF	1,763	601	3.3%	3.3%
ES	371	176	0.7%	1.0%
GO	1,329	461	2.5%	2.5%
MA	759	308	1.4%	1.7%
MG	3,628	1,160	6.7%	6.3%
MS	166	63	0.3%	0.3%
MT	435	141	0.8%	0.8%
PA	1,171	400	2.2%	2.2%
PB	853	316	1.6%	1.7%
PE	1,473	603	2.7%	3.3%
PI	462	187	0.9%	1.0%
PR	1,851	597	3.4%	3.2%
RJ	9,015	2,776	16.6%	15.1%
RN	592	245	1.1%	1.3%
RO	120	51	0.2%	0.3%
RR	36	19	0.1%	0.1%
RS	1,582	551	2.9%	3.0%
SC	630	231	1.2%	1.3%
SE	244	102	0.4%	0.6%
SP	21,405	6,918	39.5%	37.7%
TO	175	71	0.3%	0.4%
Total	54,200	18,368	100.0%	100.0%

Finally, Figure 50 shows the reduction of GHG emissions from the Reference to the Low Carbon Scenario for waste treatment. São Paulo, Rio de Janeiro, Minas Gerais and Bahia produce the largest quantities of emissions.

Figure 50: Total Emissions (MT CO2e) from Solid Waste, and Sewage and Effluents



5.2. Economic analysis

As can be observed in Table 15, and according to the Ministry of Cities (2008), municipalities with populations of over 100,000 account for the highest levels of public expenditure in the waste sector. Table 16 shows the expenditure earmarked for the sanitation sector by the Growth Acceleration Program (PAC) in 2007 - at least R$40 billion for the years 2007-2010.

Table 15 - Growth Acceleration Program (PAC) -Sanitation (2007)

Federal Resources					
Item'		Allocated		Disbursed	
		(R$)	(%)	(R$)	(%)
Water supply	Capital Financing	1.356.682.425,97	25,96	570.331.986,50	28,79
	Public budget	1.302.562.980,27		445.539.053,57	
	Total	2.659.245.406,24		1.015.871.040,07	
Sewerage	Capital Financing	2.494.808.061,55	37,77	515.480.031,47	19,70
	Public budget	1.374.614.778,70		179.654.162,18	
	Total	3.869.422.840,25		695.134.193,65	
Urban Drainage	Capital Financing	725.272.894,66	9,15	54.048.762,42	6,84
	Public budget	211.676.587,17		187.237.245,59	
	Total	936.949.481,83		241.286.008,01	
MSW	Capital Financing	17.664.400,00	0,86	25.373.699,61	1,72
	Public budget	70.214.971,00		35.447.731,68	
	Total	87.879.371,00		60.821.431,29	
Inteted Sanitation	Capital Financing	247.524.345,42	9,93	492.629.982,12	21,22
	Public budget	769.530.290,90		256.317.187,11	
	Total	1.017.054.636,32		748.947.169,23	
Pró-municípios program	Public budget	1.108.337.717,61	10,82	565.756.657,47	16,03
	Total	1.108.337.717,61		565.756.657,47	
Others	Capital Financing	462.483.737,59	5,53	60.299.337,71	5,70
	Public budget	103.574.951,54		140.665.224,35	
	Total	566.058.589,13		200.964.562,06	
Total		10.244.948.142,38	100,00	3.528.781.061,78	100,00

Source: Ministry of Cities ('Results, Projections and Actions – 2008')

Considerable amounts of investment are still needed in Brazil for collecting and treating domestic sewage. It is estimated that R$94 billion will be needed over the next 20 years in the domestic wastewaters collection and treatment area compared with approximately R$6 billion called for in the significantly expanded collection and treatment of MSW.

Investment by the private sector will vary depending on corporate policies adopted by the manufacturing sectors. Private initiatives have invested in the treatment of industrial effluents as a result of command and control actions from the environmental agencies, and above all, voluntary efforts have been made to attend the requirements of environmental management systems, social-environmental responsibility and CDM projects, which have contributed to the cash flow of such projects.

Abatement costs for the Low Carbon Scenario in the waste sector are estimated on the basis of the costs involved in introducing *per capita* (inhabitant) mitigation alternatives according to surveys conducted in official bodies and studies recently undertaken by the private and public sectors.

Estimated investment costs (with O & M costs accounting for around 10 percent of the total) were employed to estimate the costs of treating and abating greenhouse gases in the Reference and Low Carbon Scenarios.

Analyzing the results of the marginal abatement costs and of the scale of investment capital required, we confirm our view that relatively higher levels of investment need to be devoted to the treatment of domestic sewage than to solid waste treatment or the treatment of industrial effluents.

5.3. Costs and benefits

The most recent and reliable data available under national literature was used to arrive at the cost and benefit's figures. However there was a lack of sufficient data, preventing as rigourous and detailed cost and benefit survey as done for the estimation of GHG emissions. The following comments about costs and benefits of the application of a Low Carbon Scenario highlight three items: 5.3.1 (solid waste), 5.3.2 (incineration) and 5.3.3 (domestic sewage and industrial effluents). Data on costs and benefits do not cover the indirect benefits[8] linked to improvements in sanitary conditions. These indirect benefits are important but the relevant data in the local literature is too sparse to warrant their inclusion.

Within the Low Carbon Scenario certain benefits arise from activities flowing directly or indirectly from the National Sanitation Policy, such as:

- Initiatives to provide appropriate sanitation services throughout the country ('universalization and equality'), ensuring service provision for all consumers/users, particularly in the domestic waste area;
- Efforts to increase investments. Given the shortage of public investment capacity to satisfy demand, opportunities for establishing public-private partnerships and concessions for the sanitation sector need to be explored. The role of the authorities would be to regulate and supervise these activities;
- New facilitating mechanisms to reduce the negative externalities of the sanitation sector over the short to medium term;
- Initiatives to improve community wellbeing and quality of life;
- Upgrading the technical efficiency of the sanitation sector by introducing systems to ensure sustainability and promote technological innovation; and
- Upgrading service quality relating to each treatment system through better management and administration.

The benefits arising from the application of economic resources in the Low Carbon Scenarios for the waste sector can be seen as particularly efficacious instruments for incorporating the costs of the services and environmental damage into the prices of the goods, services and activities which cause them. Overall, environmental policies would be integrated with economic policies, and the principal of "polluter pays" would gain currency.

These actions should provide incentives for consumers and producers to modify behaviors

8 In a study undertaken in Baixada Santista (Rio de Janeiro), by Cetesb in the 90s, a community was divided into two: one with piped sewage and another with open air sewage. Records of diseases, medical consultations, exams, hospitalizations, medicine used and related health costs were kept. It was estimated that the costs associated with health problems in the community with open air sewage far outweighted the costs associated with the implementation of piped sewage system.

by encouraging more efficient and ecologically friendly use of resources by encouraging innovation and structural changes and strengthening compliance with existing laws.

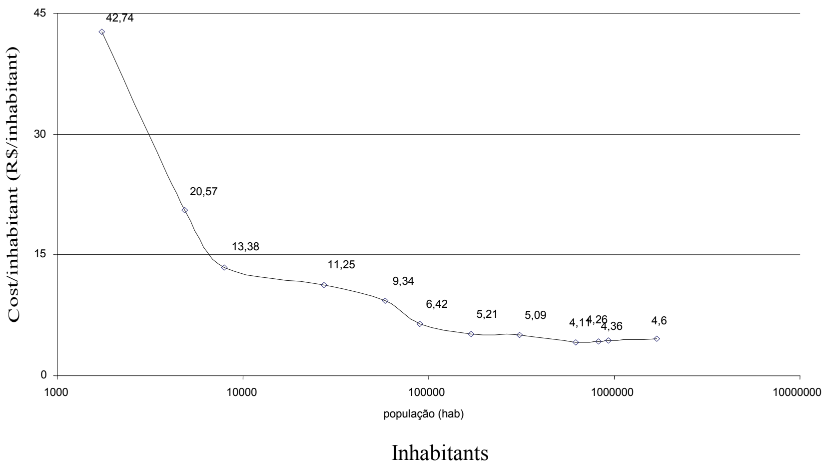
Moreover, the appropriate actions could generate funds that could be used for environmental purposes or for reducing taxes on capital, labor, and savings. They could also become efficient policy instruments for dealing with current environmental priorities such as the need to address "diffuse" sources of pollution, including GHG emissions.

5.3.1. *Solid waste*

While a clear need exists to increase investments over the next 20 years in the solid waste sector, the values projected by the PAC/Sanitation Program are nevertheless insufficient. A reasonable assessment of the costs involved has been provided by a study undertaken by the MMA (Ministério do Meio Ambiente / *Environment Ministry*) in Minas Gerais: The average costs of replacing a below-standard solid waste disposal site to comply with all the technical and legal requirements applicable to a modern MSW waste treatment facility amounts to between $4.5[9] and $6.8 per inhabitant, depending on the size of the municipality.

Considering the average present investment cost readjusted for 2030 (R$13.6/inhabitant), installation of modern MSW disposal sites would cost around R$1.8 billion in 2030, on the basis of a sample of around 140 million inhabitants. In other words, in 20 years time annual investment in such facilities would be a minimum of R$91 million/year, without taking into account spending on collection, training, education, etc. In short, upgrading substandard waste disposal sites throughout the country would call for an average investment of RS$13.9 per inhabitant.

Figure 51 - Cost of landfill impelementation (R$/inhabitant) in the state of Minas Gerais



Source: MMA/GTZ/CEF/CETEC.

On the other hand, upgrading the MSW treatment systems in terms of mitigation and sequestration, the investment costs relate to systems for collecting, burning, recovering and utilizing landfill CH_4 for energy generation purposes. Table 16 is based on data assembled from the day-to-day experience of CDM projects in Brazil.

9 Exchange rate used of 2.2R$/USD

Two landfills in the municipality of São Paulo were considered - the *Aterro Bandeirantes* which in 2007 received 6,000 tMSW/day, and the *Aterro* São *João* landfill which receives approximately 7,000 tMSW/day. These two landfills installed collection, burning, recovery and CH_4 energy providing systems.

Table 16 - Investment costs related to systems for mitigating emissions of CH4 in sanitary landfills in Brazil (2005)

Incineration	Investment cost in collection and burning of CH_4	Investment cost of recovery and using CH4 fur energy generation	Quantity of MSW disposed of	Equivalent population	Per capita investment cost of collection and burning CH_4	Per capita investment cost of energy generation
	(US$)	(US$)	(t/day)	(inhab)	(US$/inhab)	(US$/inhab)
Bandeirantes	10,773,644	20,738,636	6,000	5,000,000	2.15	4.15
São João	6,365,754	19,409,091	7,000	6,000,000	1.06	3.24

(*) Data acquired from CDM projects in the sanitary landfils of São Paulo (Bandeirantes and São João).

The average investment for installing landfills with CH_4 collection and burning systems would be around US$1.76 billion in 2030 (for a sample of around 140 million people), in order to meet future demand, without including resources needed for technology transfer, training, and education. This considers that the net average current costs adjusted to 2030 prices is US$96.8/inhabitant for installing collection and burning systems without landfill recovery and CH_4 energy generation, and including in this investment the costs required for bringing landfills up to standard. The average costs of installing landfills with systems for collecting, burning, recovering and using CH_4 for power generation is in the range of US$3.53 billion in 2030 (for around 140 million inhabitants). This figure considers average net present values adjusted to 2030 prices of US$11.8/inhabitant for the installation of systems for collection and burn of CH4 as well as the costs of bringing sanitary landfills up to standard, and excluding landfill recovery and power generation costs. These figures do not include funds needed for technology transfer, training and education.

Table 17 depicts the average costs of installing disposal and treatment facilities for MSW in Brazil's sanitary landfills.

Table 17 - Per capita cost (US$) of installing sanitary landfills (at 2030 adjusted prices)

System	Cost (US$/inhab)
Conventional sanitary landfill	13.6[(1)]
Landfill with system for collecting and burning CH_4	5.9[(2)]
Landfill with a system for collecting burning, recovery and energy generation from CH_4.	11.8[(2)]

(1) Data provided by MMA/GTZ/CAIXA/CETEC

(2) Data acquired from CDM projects in sanitary landfills of São Paulo (Bandeirantes and São João).

The shortage of space for installing landfills is one of the greatest challenges facing the solid waste management area in Brazil's large cities, particularly in the Metropolitan Regions.

The large cities in Brazil have grown in a disorganized way, producing glaring contrasts between the central and peripheral areas which lack basic infrastructure and urban services. In 2009, no free areas existed which were suitable for garbage disposal within a radius of 20km from the downtown area of the country's larger cities. The obstacles imposed by physical structures, designated protection areas, and rigid land use legislation have forced the municipal authorities and private businesses into long-haul and high-cost export of solid waste well beyond city limits (25+ km).

The most serious situation concerns the Metropolitan Regions and other large cities in view of the large quantity of waste generated. The establishment and expansion of many of Brazil's main cities occurred in an unplanned way. The city fringes, originally used for activities requiring larger areas of land such as factories, freight terminals, wholesale fruit markets and sanitary landfills, continue to be pushed further and further away from the city proper. In short, areas that could be used for installing solid waste treatment or disposal sites face physical restrictions and environmental and economic constraints arising from the lack of suitable space, and as a result, waste has to be deposited in increasingly remote areas.

5.3.2. *Incineration*

Another way of treating waste is to incinerate it and make use of the energy produced. Non-recyclable waste is reused for producing energy. In the European Union this form of treatment is accompanied by both recycling and composting and results in extremely low levels of landfill deposit. Most of the ash from the incinerated materials can be used as a raw material in the building industry. Various methods also exist to recycle or compost waste or use it for energy generation purposes. Each method may possess a specific advantage depending on the quality of the selective collection service and the resulting materials.

In order to manage waste efficiently from an environmental point of view, waste reduction and the establishment of an efficient collection system are recommended for subsequent use of waste as an energy and manufacturing input. However, cost constraints and the need for changes in the public's waste-related attitudes suggest that this stage is only possible when accompanied by ongoing improvements in the municipal waste systems.

Before 2009 the use of incineration technology in Brazil was confined to medical waste. As of 2009, there was only one MSW incinerator in operation (as a pilot project) on the Rio de Janeiro Federal University campus. Unfortunately data on the investment and operational costs of the system is not available, and even if it were the information would not be appropriate for using in this Scenario which is concerned only with incineration systems in municipalities with populations of over 3 million.

The São Paulo State program for using MSW and other waste for energy purposes, under the aegis of a working group created by Joint Resolution SSE/SMA 49/2007, prepared a study (Executive Summary, July 2008) which benefited directly from the results of the Technical Cooperation Agreement signed between the State of São Paulo and Bavaria (Germany), coordinated on the Brazilian side by the São Paulo Environment Secretariat. This study examined grid or fluidized bed type incineration systems with a throughput of 2,400 tons/day. The investment costs can be seen in Table 18 below.

Table 18 - Investment costs related to MSW incineration systems (2008)

	Investment cost of incineration without cogeneration of energy	Investment cost of incineration with cogeneration of energy	Equivalent population	Per capita investment cost of incineration without cogeneration of energy	Per capita investment cost of incineration with cogeneration of energy
Incineration	(1,000,000 US$)(1)	(1,000,000 US$)(1)	(1,000 inhab)	(US$/inhab)	(US$/inhab)
01 module (600t/day)	103.3	98.0	750	137.9	130.6
02 modules (1,200t/day)	184.5	174.9	1,500	123.0	116.6
04 modules (2,400t/day)	329.4	312.3	3,000	109.8	104.1

(1) Data from SSE/SMA initial study, July 2008.

With the average present investment costs adjusted at 2030 prices to US$227.3/inhabitant for installing CH_4 energy-producing incineration systems, the average investment for installing such systems would be US$12.3 billion in 2030 (for a sample of approximately 50 million inhabitants representing the population of the 8 Metropolitan Regions under consideration) in order to satisfy demand - without taking into account the need for resources to be spent on technology transfer, training and education. The average costs of installing MSW incineration can be seen at Table 19.

Table 19 - Per capita costs (US$) of installing incinerators in Brazil (at 2030 adjusted prices)

System	Cost (US$/inhabitant)
Incineration without energy cogeneration	204.5(1)
Incineration with energy cogeneration	227.3(1)
Incineration with energy cogeneration and fossil waste recycling	250

1) Data from SSE/SMA initial study in July , 2008.

5.3.3. *Domestic sewage and industrial effluent*

Over the next 20 years priority should be given to increasing investments for treating domestic sewage. Table 20 shows that the expenditure necessary on sewage treatment will be between US$45.4 to US$90.9/inhabitant at 2030 prices depending on the size and technical design of the system used.

The following table lists the cost of installing sewage treatment systems by region. These numbers were prepared by the JNS/AQUAPLAN with the support of the UNDP (United Nations Development Program) and the World Bank (UNDP/World Bank Program for Sanitation Sector Modernization- PMSS) "... *assessing the investment requirements for universalizing water supply and sewage treatment collection/treatment in Brazil*".

Table 20 - Cost of installing sewage treatment[10]

State	Average Treatment Price (US$/inhab)		
	Small	Medium	Large
Acre	45.9	71.9	97.5
Amapá	40.5	62.5	84.2
Amazonas	45.8	73.8	101.4
Pará	40.2	62.7	84.8
Rondônia	49.6	79.4	108.6
Roraima	48.0	82.1	112.8
Tocantins	47.3	78.6	108.6
Alagoas	39.0	61.6	83.8
Bahia	41.9	66.0	89.6
Ceará	36.6	57.8	78.3
Maranhão	40.7	63.2	85.3
Paraíba	39.7	63.7	87.3
Pernambuco	40.3	65.6	90.6
Piauí	35.9	58.6	80.8
Rio Grande do Norte	38.9	62.6	85.7
Sergipe	40.5	62.9	84.6
Espírito Santo	38.4	61.0	83.1
Minas Gerais	39.1	65.2	90.7
Rio de Janeiro	45.6	73.1	100.1
São Paulo	44.5	73.4	101.5
Paraná	41.9	73.7	104.0
Rio Grande do Sul	46.5	74.3	100.8
Santa Catarina	43.9	72.7	100.7
Distrito Federal	41.3	68.4	94.7
Goiás	47.0	75.4	102.9
Mato Grosso	41.9	72.5	102.4
Mato Grosso do Sul	43.8	71.7	98.9

(*)Study by JNS/Acquaplan consortium.

Source: PMSS II (2003)

Considering the costs of installing sewage treatment systems of the combined biological "anaerobic and aerobic" type, the average investment per inhabitant at 2030 prices throughout Brazil will need to be approximately US$181.8. The total cost of this type of undertaking would be around US$38.2 billion in 2030 assuming total waste treatment coverage, without taking account of the costs of waste collection, training and education.

To arrive at the costs of CH_4 collection and burning systems in sewage treatment plants, information was secured on similar types of systems currently operating in Brazil from the publication *Projects with Federal Public Funding* (Pró-Saneamento, PRODES and Caixa Econômica Federal). The figures in Table 21 below are provided by the municipality of Campinas (in São Paulo state) which recently installed a CH_4 collection and burning system in its ETEs.

10 The price includes the treatment plant, interceptor pipes and lifting equipment. For small municipalities the costs of treatment of installation of an anaerobic reactor with lagoons were estimated. In the larger municipalities the cost corresponds to the installation of a treatment plant using activated sludges with conventional aeration. For medium-sized municipalities a median value was estimated, using combined anaerobic/aerobic systems.

Table 21 - Investment costs of mitigating CH4 emissions in ETEs in 2008

ETE	Investment cost of a system for collection and burning CH_4 (US$)	Equivalent population (1000 inhab).	Per capita investment cost of a system for collection and burning CH_4 (US$/inhab).
Capivari 1 Campinas – SP	195,454.50[1]	50	3.9

(1) Data from suppliers of FOKAL equipment (www.fokal.com.br).

Assuming an investment cost of R$16.00/inhabitant in 2003, the average cost of installing collection and burning systems without landfill CH_4 recovery and energy use would be around R$3.36 billion in order to meet future demands, without taking into account the resources needed for technical transfer, training, and education.

The average investment costs needed in Brazil to install sewage treatment equipment of the combined "anaerobic + activated sludges" type can be seen in Table 22.

Table 22 - Costs of installing sewage treatment (at 2030 adjusted prices)

Systems	Investment (US$/inhab)
ETE " Anaerobic Reactor + activated sludges "	181.8[1]
ETE "Anaerobic Reactor + activated sludges " with collection and burning of CH_4	7.3[2]

(1) Data from MSS II (2003) –assembled by JNS/Acquaplan consortium.
(2) Data from suppliers of FOKAL equipment (www.fokal.com.br)

The abatement costs for the Low Carbon Scenario in the wastes sector are estimated based on the *per capita* costs of employing mitigation methods according to surveys undertaken in official bodies and data from recent public and private sector projects. These investment costs were used (allowing for 10 percent expenditure on O&M) for estimating the abatement costs. The investment costs for the treatment systems and GHG emissions abatement of the Reference and Low Carbon Scenarios were estimated in the same way.

5.4. Marginal abatement costs and Break Even Carbon Price

An economic analysis of the Low Carbon Scenario is desirable in order to inform government and society of the costs and benefits of minimizing GHG emissions. An analysis can also help to clarify the types of sequestering and mitigation methods to be implemented. However, the following points are worth considering:

No single method exists for preparing an economic analysis of these options: a number of different methods can be adopted for each Low Carbon Scenario to reflect the different viewpoints and economic concerns of government, society and/or the private sector. Two approaches were chosen:

i. A microeconomic evaluation of the costs and benefits of introducing sequestering and mitigation measures; and

ii. A macroeconomic evaluation of the same measures to reflect government policies and the relevant legal regulations applied to the sector.

A combined evaluation of the measures in the different areas is not a simple task. Many of the measures considered are implemented in different contexts, e.g. some can apply in the federal or local public sector economic context while others are specific to the private sector. Given that the public and private sectors understandably adopt different economic and management approaches, a two-pronged cost/benefit analysis procedure was adopted for informing decision makers - the first from a "social" and the second from a "private" viewpoint.

The "social" approach tends to provide a basis for sectorial cross-referenced comparison for the Low Carbon Scenarios. The marginal abatement cost is therefore calculated using a social discount rate of 8 percent. In order to facilitate the comparison, the Marginal Abatement Costs of all the mitigation and sequestering measures proposed was arrived at by grouping together in one simple diagram (i) the official data on investment costs available in the sanitation sector with (ii) the data on GHG emissions abatement potential.

The "private sector" approach focuses on measures that could be attractive to economic agents in terms of possible investment in the sector in view of the 'carbon component' in the Reference Scenario. In this respect the Clean Development Mechanism (CDM) Projects for the sector inspired by the Kyoto Protocol are important, and possible additional recipes for facilitating the implementation of the mitigation and sequestering measures outlined here. The private sector approach would basically involve encouraging economic agents to assess the profit potential of investing in a Low Carbon Scenario, with the financial carbon market providing real incentives in terms of a Minimum Break Even Carbon Price expressed in US$ per ton of CO_2 equivalent. Other economic mechanisms could also be employed as incentives for decision makers to implement the Low Carbon Scenario proposed in this report, (e.g. the potential profits from converting biogas as an energy source).

5.4.1. *Marginal abatement cost*

The marginal abatement cost indicates the difference between normal waste treatment costs and the total costs when the costs of the GHG emissions mitigation projected in the Low Carbon Scenario are incorporated. The marginal abatement cost was estimated at a discount rate of 8 percent, while the break even cost was estimated at 12 percent. Both were defined on the basis of the current situation in Brazil.

The average current cost of abating emissions for the period between 2010 and 2030 in the Low Carbon Scenario is presented in Table 23 and illustrated in Figure 52. In Table 24 the figures in the end column indicate that the average cost of abatement is US$1.33/t$CO_2$e for the MSW Low Carbon Scenario, US$1.33/t$CO_2$e for the domestic sewage scenario and US$103.30/t$CO_2$e for the industrial effluents scenario. The significant difference between these numbers is due to the high investment costs needed to construct ETEs when compared to the large quantities of CH_4 generated in the landfills and the costs of burying, capture and burning the CH_4 generated in the landfills.

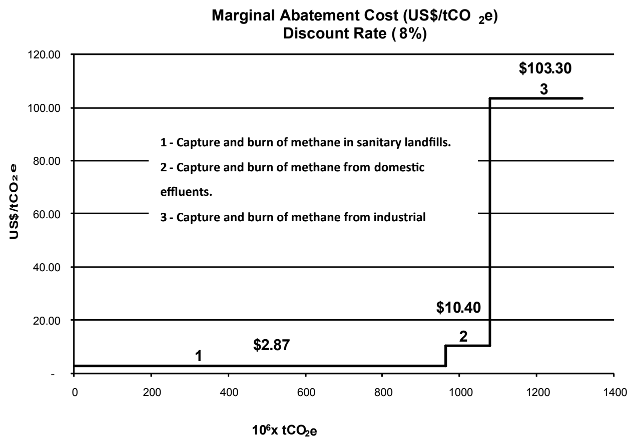
Table 23 - Current abatement costs: 2030 Low Carbon Scenario

Mitigation or sequestering options	Urban population to receive services (10^6.hab)	Current median abatement cost (10^6.US$)	Potential gross abatement between 2010 and 2030 (10^6.tCO_2e)	Current median abatement cost (US$/$tCO_2e$)
Reference Scenario for MSW	138.54(1)	-	-	-
Low Carbon Scenario for MSW with methane flaring and 75% collection efficiency of CH_4	138.54(1)	2,763.88	962.69	2.87
Reference Scenario of domestic sewage	209.91(2)	-	-	-
Low Carbon Scenario for domestic sewage with 100% CH_4 collected and burned.	209.91(3)	1,204.01	115.77	10.40
Reference Scenario for industrial effluent	93.58(4)	-	-	-
Low Carbon Scenario for industrial effluent with 100% CH_4 collected and burned.	467.90(5)	24,622.25	238.35	103.30

Obs: US dollar exchange in 2009 R$2,20/US$.
(1) 66 percent of urban population in 2030 benefiting from MSW treatment.
(2) 10 percent of urban population in 2030 benefiting from sewage treatment.
(3) 100 percent of the urban population in 2030 benefiting from sewage treatment.
(4) Population equivalent to liquid effluent polluting load originating in the manufacturing and similar setors
(5) Population equivalent to liquid effluent polluting load originating in the growth projection of manufacturing and similar sectors

Figure 52 below gives an idea of the large quantity and the low cost of destroying GHG represented by the 2030 Low Carbon Scenario. The gross abatement potential is around 73.1 percent of the mass of MSW - related CO_2e avoided. Approximately 8.8 percent of the mass of CO_2e is avoided in the treatment of sewage and the remaining 18.1 percent avoided in industrial effluent treatment.

Figure 52 - Marginal Abatement Costs



5.4.2. *Break Even Carbon Price*

The *Break Even Carbon Price* is the term used in the Low Carbon Scenario for describing the costs of the incentive that enables the proposed mitigation measure to generate a return that is equal to or greater than the benchmark Internal Rate of Return (IRR) required by the private sector.

The *Break Even Carbon Price* was estimated with a discount rate of 12 percent (Benchmark IRR) in order to represent a figure that was closer to reality in the financing and development of projects concerned with legal modalities involving Public and Private Partnerships (PPPs).

The current *Break Even Carbon Price* values are summarized in Table 24: (i) US$6.94/tCO2e for the MSW sector; (ii) US$33.05/tCO2e for the domestic wastewater sector; and (iii) US$250.69/ tCO2e for the industrial effluents sector. The substantial difference between these values is due to the relatively low costs involved in installing equipment to capture and burn biogas in sanitary landfills, while the sewage anaerobic treatment systems need to take into account the higher costs of construction, operation and maintenance of the entire sewage treatment system including capture and burning of biogas and dealing with sludges (part and parcel of the treatment process). A different situation can be observed with respect to the industrial effluents, where a significant segment of the manufacturing sector already possesses treatment systems currently in operation, and where investment needs to be more directed towards the installation of equipment to capture and burn biogas. This should take into account the increased load resulting from economic and manufacturing development. Table 25 contains a summary of the marginal abatement costs with a discount rate of 8 percent and an indication of the scale of investment required.

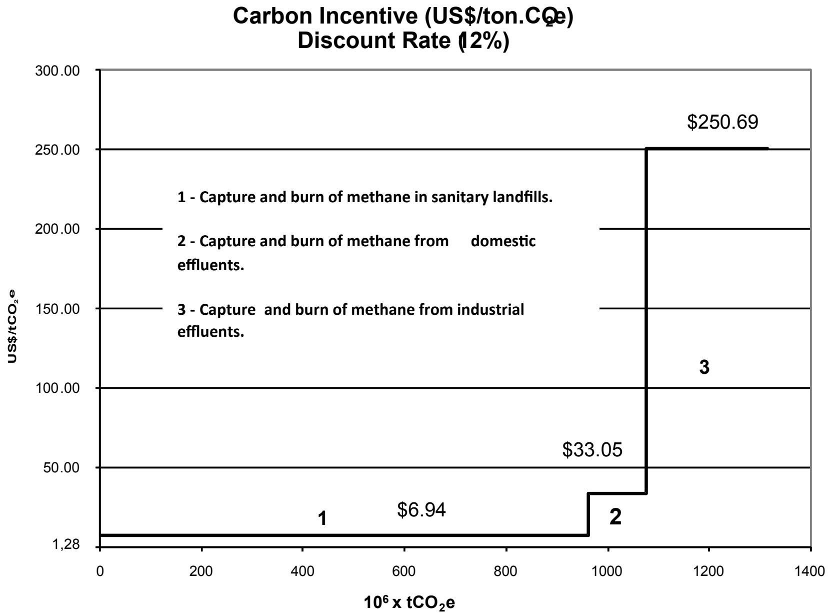
Table 24 - Marginal abatement costs, Break Even Carbon Price and scale of investment for 2030 Low Carbon Scenario

Mitigation options	Values (US$/t$CO_2$e)					
	Potential gross abatement between 2010 and 2030	Marginal costs of abatement (i = 8%)	Break Even Price (i = 12%)		Scale of investment	
				Incremental		Incremental
MSW Low Carbon Scenario with landfill burning of CH_4 at 75% collection efficiency rate.	962.69	2.87		6.94		3.85
Domestic sewage Low Carbon Scenario with 100% of the biogas captured and burned.	115.77	10.40		33.05		13.85
Industrial effluents Low Carbon Scenario with 100% of the biogas captured and burned.	238.35	103.30		250.69		122.74

Key: i = discount rate

The variations in the CO_2e. break even and incremental incentive prices are presented in Figure 53.

Figure 53 - Break Even Carbon Prices



5.5. Financing requirements

Solid waste is responsible for over 80 percent of gross potential GHG emissions. The remaining 20 percent is accounted for by sewage and effluents. However, in cost-benefit terms, better value carbon mitigation benefits can be obtained by installing sanitary landfills to capture and burn CH_4, as indicated by Figure 54 below.

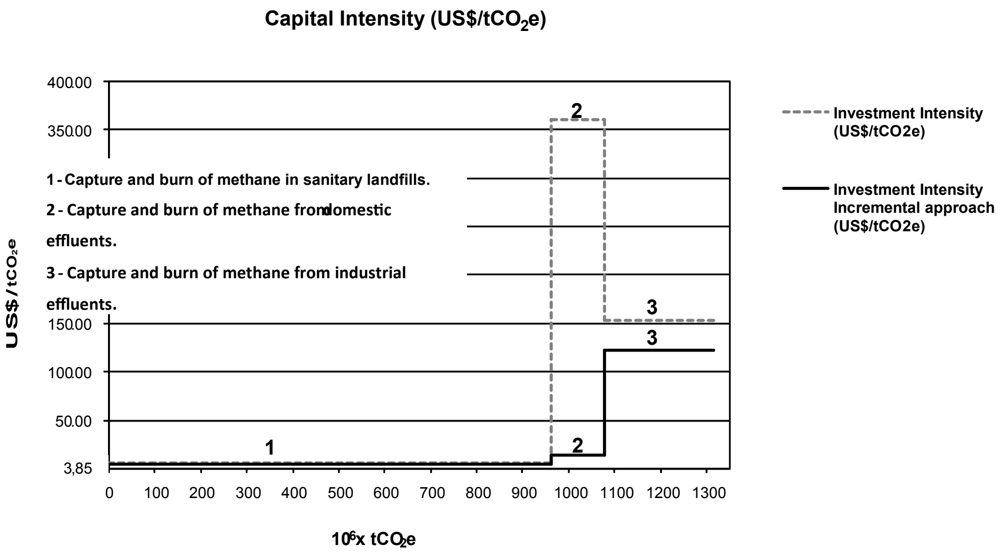
While the waste sector calls for substantial financing by Brazilian development agencies, the prospect of funding by international or multilateral agencies should not be discarded.

The scale of investment in the waste sector is linked to the capacity of the public and private sectors to achieve the 'universalization of sanitation services' projected in the National Sanitation Policy. It follows that the amount of investment in the alternative technologies presented by the Low Carbon Scenario can be seen as an achievable objective within the time horizon of the Scenario.

Figure 54 indicates the scale of investment for the waste sectors divided into MSW, domestic sewage, and industrial effluents. This figure indicates that a need exists for investment to flow from a range of public policies - which should be pursued preferably in conjunction with private sector initiatives.

The investment costs in this report are based upon official data issued by the Federal Government. The Low Carbon Scenario will certainly contribute to ensuring that the required investments are made in the sector by 2030.

Figure 54 - Scale of Investment



6. Conclusion

The Reference Scenarios for GHG emissions in the waste sector show an increase in emissions from 63 to 99.2 $MtCO_2e$ between 2000 and 2030, signifying a percentage increase of around 57 percent. The Low Carbon Scenario shows that it is possible to avoid emissions in year 2030 by reducing the projected 99.2 to 18.10 $MtCO_2e$ - a reduction of just over 80 percent in emissions. Burning CH_4 generated by sanitary landfills will be the most important development, involving a potential reduction of the order of 55.10 $MtCO_2e$. The Low Carbon Scenario for solid waste, domestic sewage and industrial effluents sector foreshadows an expansion of anaerobic systems for treating domestic sewage and industrial effluents and burning all the CH_4 generated, reducing to zero the emissions resulting from sewage and effluent treatment.

We have also considered events (not included in the Reference Scenario) such as the possibility of increased quantities of waste for depositing in landfills. This could be caused by several factors, one of them being the expansion of collection services which could be regarded as an improvement in public health terms but which in the longer term could lead to an increase in greenhouse gas emissions. Also considered is a possible reduction of waste quantities for landfill disposal. This could result from, for example, stepped-up environmental education programs, greater public awareness of environmentally friendly practices to reduce waste generation at source, and reusing/recycling waste materials. Despite being highly recommendable from all points of view, the latter cannot be regarded as the most efficient in terms of GHG reduction. Incineration results in an increase in GHG emissions during the first years of its implementation, which would indicate this option may call for compensatory measures to be taken to counter the possible GHG emissions.

Of all the environmental practices concerned with waste treatment the most interesting is that which predicates zero generation of waste – in other words the most desirable option for the environment would not be CH_4 collection in the sanitary landfills but the non-generation of waste itself. Since such a scenario is improbable the most interesting of the alternatives evaluated has to be the recovery and burning of CH_4.

The co-benefits produced by disposing of MSW in sanitary landfills and burning CH_4, and using anaerobic methods to treat sewage and effluents, are calculated in the economic evaluation of the scenarios. Moreover, the sanitation costs spreadsheets do not quantify (i) the economic advantages resulting from avoiding diseases or (ii) improvements in the quality of life for the population.

Substantial investments are required in Brazil to deal with the collection and treatment of effluents. Given the nonexistence of the required infrastructure, the abatement costs involved in treating effluents are higher than those for solid waste.

The various estimate uncertainties outlined in chapters 3.2.8 and 4.2.6 arise from the scarcity of data in the relevant Brazilian scientific literature. In addition, the unquantified uncertainties relating to the hypotheses raised in the Reference and Low Carbon Scenarios encompass the greatest fragility of the study. The uncertanty related to the cost and benefit data was not quantified, however, the data research strategy deployed helped ensure the utilization of the best available information.

It is estimated that in the waste sector investments of around R$6 billion are needed over the next 20 years for the collection and treatment of solid waste and R$94 billion in the domestic sewage collection and treatment area. New investments by the private sector could vary substantially, depending on the corporate policies adopted by the manufacturing sector, but it can already be affirmed that the CDM projects will make a substantial contribution to increasing project cash flows.

A program of incentives in the context of a Low Carbon Scenario would help to focus more investment on the waste sector, particularly for developing new technologies designed to lower carbon emissions and to convert waste into energy.

7. Annexes

7.1. Metropolitan regions

Given the high costs of installation and O&M, incineration is only economically viable in large-scale projects in large cities with populations of over 3 million generating at least 2400 tons/day of MSW.

According to IBGE[11] (2008) the total population of urban areas of this kind is 54.728.762.

Eight large urban areas have been identified in Brazil which possess a population of over 3 million as follows:

7.1.1. Salvador

Municipalities	Total population
Salvador Camaçari Lauro de Freitas Simões Filho Candeias Dias d'Ávila Vera Cruz São Francisco do Conde Itaparica Madre de Deus Mata de São João São Sebastião do Passé Pojuca	3.799.589

7.1.2. Fortaleza

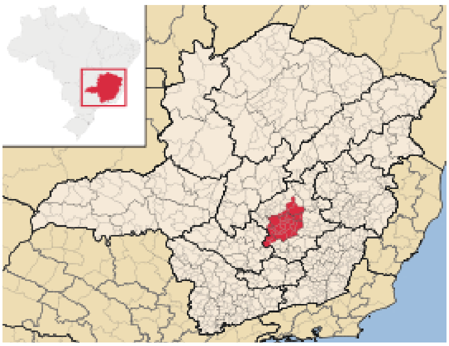
Municipalities	Total population
Fortaleza Caucaia Aquiraz Pacatuba Maranguape Maracanaú Eusébio Guaiúba Itaitinga Chorozinho Pacajus Horizonte São Gonçalo do Amarante	3.517.375

11 Population estimates for 1 July 2008 (PDF). Brazilian Geography and Statistics Institute (IBGE) (29 August 2008). Page visited on September 9th, 2008.

7.1.3. *Recife*

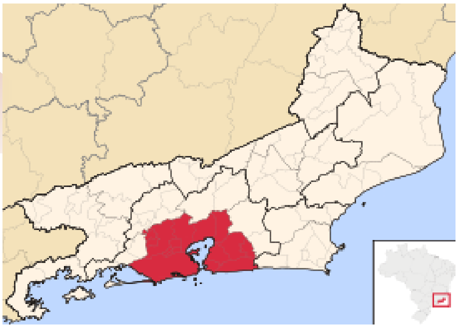
Municipalities	Total population
Recife Jaboatão dos Guararapes Olinda Paulista Abreu e Lima Igarassu Camaragibe Cabo de Santo Agostinho São Lourenço da Mata Araçoiaba Ilha de Itamaracá Ipojuca Moreno Itapissuma	3.731.719

7.1.4. *Belo Horizonte*



Municipalities	Total population
Baldim Belo Horizonte Betim Brumadinho Caeté Capim Branco Confins Contagem Esmeraldas Florestal Ibirité Igarapé Itaguara Itatiaiuçu Jaboticatubas Juatuba Lagoa Santa Mário Campos Mateus Leme Matozinhos Nova Lima Nova União Pedro Leopoldo Raposos Ribeirão das Neves Rio Acima Rio Manso Sabará Santa Luzia São Joaquim de Bicas São José da Lapa Sarzedo Taquaraçu de Minas e Vespasiano	5.031.438

7.1.5. *Rio de Janeiro*



Municipalities	Total population
Belford Roxo Duque de Caxias Guapimirim Itaboraí Itaguaí Japeri Magé Mangaratiba Maricá Mesquita Nilópolis Niterói Nova Iguaçu Paracambi Queimados Rio de Janeiro São Gonçalo São João de Meriti Seropédica Tanguá	11.812.482

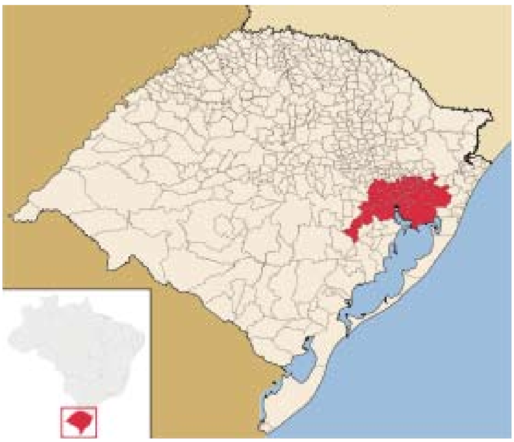
7.1.6. *São Paulo*

Municipalities	Total population
Arujá Barueri Biritiba-Mirim Caieiras Cajamar Carapicuíba Cotia Diadema Embu Embu-Guaçu Ferraz de Vasconcelos Francisco Morato Franco da Rocha Guararema Guarulhos Itapevi Itapecerica da Serra Itaquaquecetuba Jandira Juquitiba Mairiporã Mauá Mogi das Cruzes Osasco Pirapora do Bom Jesus Poá Ribeirão Pires Rio Grande da Serra Salesópolis Santa Isabel Santana de Parnaíba Santo André São Bernardo do Campo São Caetano do Sul São Lourenço da Serra São Paulo Suzano Taboão da Serra Vargem Grande Paulista	19.616.060

7.1.7. Curitiba

Municipalities	Total population
Adrianópolis Agudos do Sul Almirante Tamandaré Araucária Balsa Nova Bocaiúva do Sul Campina Grande do Sul Campo Largo Campo Magro Cerro Azul Colombo Contenda Curitiba Doutor Ulysses Fazenda Rio Grande Itaperuçu Lapa Mandirituba Pinhais Piraquara Quatro Barras Quitandinha Rio Branco do Sul São José dos Pinhais Tijucas do Sul Tunas do Paraná	**3.260.292**

7.1.8. Porto Alegre



Municipalities	Total population
Alvorada Cachoeirinha Campo Bom Canoas Estância Velha Esteio Gravataí Guaíba Novo Hamburgo Porto Alegre São Leopoldo Sapiranga Sapucaia do Sul Viamão Dois Irmãos Eldorado do Sul Glorinha Ivoti Nova Hartz Parobé Portão Triunfo Charqueadas Araricá Nova Santa Rita Montenegro Taquara São Jerônimo Arroio dos Ratos Santo Antônio da Patrulha Capela de Santana	**3.959.807**

7.2. *CDM projects in the waste and effluents sector in Brazil*

The examples of projects being implemented in Brazil are confined to the private sector and PPPs.

Data on the mitigation projects for sanitary landfills that are being implemented can be observed in Tables 25, 26,27 and 28 below, containing UNFCCC data. In early 2009 a total of 25 CDM projects had been recorded of which 20 projects deal with collection and burning systems and the other five with recovery and energy generation.

At the beginning of 2009 a total of 6 CDM project activities focused on composting were at the validation stage. These projects did not require the use of MSW.

Incineration is currently used for treating hazardous waste. A number of private industrial incinerators are in operation. These provide incineration for third parties, with the majority of them located in the states of São Paulo (average capacity of 26,000 t/year), Rio de Janeiro (average capacity of 11,500 t/year), Bahia (average capacity of 14,400 t/year) and Alagoas (average capacity of 11,500 t/year).

The private sector is undertaking over 50 CDM project activities in the effluents treatment sector which are either already registered or at the validation stage.

The following list of CDM projects was available on the UNFCCC site in May 2009.

Tabela 25 – CDM Sanitary landfill projects

Name of project	State	Status	Type/Subtype	Methodology	$ktCO_2$ (*)
Salvador Da Bahia landfill gas management project (NM4)	BA	Registered	Biogás/ Flare	AM2	6667
Onyx landfill gas recovery project - Trémembé, Brazil (NM21)	SP	Registered	Biogás/ Flare	AM11	701
Caieiras landfill gas emission reduction	SP	Registered	Biogás/ Flare	ACM1	2441
ESTRE's Paulínia Landfill Gas Project (EPLGP)	SP	Registered	Biogás/ Flare	AM3	1488
Project Anaconda	SP	Registered	Biogás/ Flare	ACM1	699
Canabrava Landfill Gas Project	BA	Registered	Biogás/ Flare	ACM1	1321
Aurá Landfill Gas Project	PA	Registered	Biogás/ Flare	ACM1	1981
Central de Resíduos do Recreio Landfill Gas Project (CRRLGP)	RS	Registered	Biogás/ Flare	ACM1	647
ESTRE Itapevi Landfill Gas Project (EILGP)	SP	Registered	Biogás/ Flare	ACM1	486
Quitaúna Landfill Gas Project	SP	Registered	Biogás/ Flare	ACM1	581
SANTECH – Saneamento & Tecnologia Ambiental Ltda.	SC	Registered	Biogás/ Flare	ACM1	153
CTRVV Landfill emission reduction project	ES	Registered	Biogás/ Flare	ACM1	455
Probiogas - JP-João Pessoa Landfill Gas Project	PR	Registered	Biogás/ Flare	ACM1+ACM2	1039
Proactiva Tijuquinhas Landfill Gas Capture and Flaring project	SC	Registered	Biogás/ Flare	ACM1	574
Estre Pedreira Landfill Gás Project (EPLGP)	SP	Registered	Biogás/ Flare	ACM1+ACM2	866
Terrestre Ambiental Landfill Gás Project	SP	Registered	Biogás/ Flare	ACM1+ACM2	487
Embralixo/Araúna - Bragança Landfill Gas Project (EABLGP)	SP	Registered	Biogás/ Flare	ACM1+ACM2	331
URBAM/ARAUNA - Landfill Gas Project (UALGP)	SP	Registered	Biogás/ Flare	ACM1	571
Alto-Tietê landfill gas capture project	SP	Registered	Biogás/ Flare	ACM1	2323
Manaus Landfill Gas Project	AM	Validation	Biogás/ Flare	ACM1+ACM2	3808
Natal Landfill Gas Recovery Project	RN	Validation	Biogás/ Flare	ACM1	498
Laguna Landfill Methane Flaring	SC	Validation	Biogás/ Flare	ACM1	67
Marilia/Arauna Landfill Gas Project	SP	Validation	Biogás/ Flare	ACM1	170
CGR Guatapará landfill Project	SP	Validation	Biogás/ Flare	ACM1	181
Brazil NovaGerar landfill gas to energy project (NM5)	RJ	Registered	Biogás/Energy generation	AM3	2937
Landfill gas to energy project at Lara landfill, Mauá	SP	Registered	Biogás/Energy generation	AM3	4726
Brazil MARCA landfill gas to energy project	ES	Registered	Biogás/Energy generation	AM3	1728
Bandeirantes Landfill Gas to Energy Project (BLFGE).	SP	Registered	Biogás/Energy generation	ACM1	9494
São João Landfill Gas to Energy Project	SP	Registered	Biogás/Energy generation	ACM1	3766
Feira de Santana Landfill Gas Project	BA	Registered	Biogás/Energy generation	ACM1+ACM2	194
Projeto de Gás de Aterro TECIPAR – PROGAT	SP	Validation	Biogás/Energy generation	ACM1	350

Name of project	kCERs	kCERs Expected (**)	Emissions Success	Date of Registration	Installed Energy (***)
Salvador Da Bahia landfill gas management project (NM4)	46	591	8%	15/08/2005	
Onyx landfill gas recovery project - Trémembé, Brazil (NM21)	84	141	60%	24/11/2005	
Caieiras landfill gas emission reduction	103	553	19%	09/03/2006	
ESTRE's Paulínia Landfill Gas Project (EPLGP)	251	229	110%	03/03/2006	
Project Anaconda	22	126	18%	15/12/2006	
Canabrava Landfill Gas Project	9	174	5%	08/04/2007	
Aurá Landfill Gas Project				30/04/2007	
Central de Resíduos do Recreio Landfill Gas Project (CRRLGP)				31/12/2006	
ESTRE Itapevi Landfill Gas Project (EILGP)	30	40	75%	17/08/2007	
Quitaúna Landfill Gas Project				27/05/2007	
SANTECH – Saneamento & Tecnologia Ambiental Ltda.				19/02/2009	
CTRVV Landfill emission reduction project				28/05/2008	
Probiogas - JP-João Pessoa Landfill Gas Project				30/01/2008	
Proactiva Tijuquinhas Landfill Gas Capture and Flaring project				13/08/2008	
Estre Pedreira Landfill Gás Project (EPLGP)	40	49	82%	12/02/2008	
Terrestre Ambiental Landfill Gás Project	26	32	80%	06/05/2008	
Embralixo/Araúna - Bragança Landfill Gas Project (EABLGP)				15/10/2007	
URBAM/ARAUNA - Landfill Gas Project (UALGP)				14/10/2007	
Alto-Tietê landfill gas capture project				29/05/2008	
Manaus Landfill Gas Project					18,0
Natal Landfill Gas Recovery Project					
Laguna Landfill Methane Flaring					
Marilia/Arauna Landfill Gas Project					
CGR Guatapará landfill Project					
Brazil NovaGerar landfill gas to energy project (NM5)	67	887	8%	18/11/2004	12,0
Landfill gas to energy project at Lara landfill, Mauá	303	1076	28%	15/05/2006	10,0
Brazil MARCA landfill gas to energy project				23/01/2006	11,0
Bandeirantes Landfill Gas to Energy Project (BLFGE).	2868	5113	56%	20/02/2006	22,0
São João Landfill Gas to Energy Project	528	914	58%	02/07/2006	20,0
Feira de Santana Landfill Gas Project				12/07/2008	
Projeto de Gás de Aterro TECIPAR – PROGAT					6,5

(*) In 2012.
(**) Defined as the CERs emitted due to the number of CERs expected in the sam e period..
(***) At end 2012.

Table 26 – CDM Composting projects

Name of project	State	Status	Type/Subtype	Methodology	$ktCO_2$(*)	kCERs	kCERs Expected(**)	Emission Success	Date of Registration	Installed Energy (***)
Lixo Zero Composting Project	RJ	Validation	Biogás/ Composting	AM25	312					
Organoeste Dourados & Andradina Composting Project	MT e SP	Validation	Biogás/ Composting	AMS-III.F.	108					
Organoeste Apucarana & Mandaguaçu Composting Project	PR	Validation	Biogás/ Composting	AMS	84					
Organoeste Aracruz Composting Project	ES	Validation	Biogás/ Composting	AMS	89					
Organoeste Contenda & Campo Grande Composting Project	PR e MS	Validation	Biogás/ Composting	AMS	82					
VCP Jacareí Sludge Composting Project	SP	Validation	Biogás/ Composting	AMS	75					

(*) In 2012.
(**) Defined as the CERs emitted due to the number of CERs expected in the sam e period..
(***) At end 2012.

Table 27 – CDM Liquid effluents projects

Name of project	State	Status	Type/Subtype	Methodology	$ktCO_2$ (*)	kCERs	kCERs Expected(**)	Emission Success	Date of Registration	Installed Energy (***)
GHG emissions reductions from improved industrial wastewater treatment in Embaré	MG	Validation	Biogás/Energy generation	AMS-I.D.+ AMS-III.H.	34					
Irani Wastewater Methane Avoidance Project	SC	Registered	Agriculture/ Biogás	AMS-III.I.	278				19/01/08	
BRASCARBON Methane Recovery Project BCA-BRA-01	SC, SP e MG	Registered	Agriculture/ Biogás	AMS-III.D.	189				16/03/09	
Project JBS S/A – Slaughterhouse Effluent Treatment – Andradina Unit	SP	Validation	Agriculture/ Biogás	AMS-III.H.	128					
Project JBS S/A – Slaughterhouse Wastewater Aerobic Treatment – Vilhena Unit	RO	Validation	Agriculture/ Biogás	AMS-III.I.	122					
JBS S/A – Slaughterhouse Wastewater Aerobic Treatment – Barra do Garças Unit	MT	Validation	Agriculture/ Biogás	AMS-III.I.	176					
Vinasse Anaerobic Treatment Project - Cooperval Ltda	PR	Validation	Agriculture/ Biogás	ACM14	404					

Table 28 - CDM rural waste projects

Name of project	State	Status	Type/sub-type	Methodology	$ktCO_2$ (*)
Perdigão Sustainable Swine Production 01 – Methane capture and combustion	GO and RS	Request review	Agriculture/ Biogas	AMS-III.D.	230
GHG capture/combustion from swine manure man. systems at Faxinal dos Guedes and Toledo	PR	Registered	Agriculture/ Biogas	AM6	218
Granja Becker GHG mitigation project (NM34)	MG	Registered	Agriculture/ Biogas *flare*	AM16	43
AWMS GHG Mitigation Project BR05-B-01, Minas Gerais Brazil	MG	Registered	Agriculture/ Biogas	AM16	465
AWMS GHG Mitigation Project BR05-B-03	MG, GO and MT	Registered	Agriculture/ Biogas	AM16	1426

AWMS GHG Mitigation Project BR05-B-02, Minas Gerais / São Paulo	MG and SP	Registered	Agriculture/ Biogas	AM16	1192
AWMS GHG Mitigation Project BR05-B-04, Paraná, Santa Catarina, and Rio Grande do Sul	PR. SC and RS	Registered	Agriculture/ Biogas	AM16	717
AWMS GHG Mitigation Project BR05-B-05, Minas Gerais and São Paulo	MG and SP	Registered	Agriculture/ Biogas	AM16	572
AWMS GHG Mitigation Project BR05-B-07, Mato Grosso, Minas Gerais, and Goiás	MS, MG	Registered	Agriculture/ Biogas	AM16	1112
AWMS GHG Mitigation Project BR05-B-09	GO and MG	Registered	Agriculture/ Biogas	AM16	383
AWMS GHG Mitigation Project BR05-B-06, Bahía	BA	Registered	Agriculture/ Biogas	AM16	100
AWMS GHG Mitigation Project BR05-B-10, Minas Gerais, Goias, Mato Grosso, and Mato Grosso do Sul	MG, GO and MT	Registered	Agriculture/ Biogas	AM16	654
AWMS GHG Mitigation Project BR05-B-08, Paraná, Santa Catrina, and Rio Grande do Sul	PR, SC and RS	Registered	Agriculture/ Biogas	AM16	110
AWMS GHG Mitigation Project BR05-B-11, Mato Grosso, Minas Gerais and São Paulo	MT, MS and SP	Registered	Agriculture/ Biogas	AM16	463
AWMS GHG Mitigation Project BR05-B-12, Mato Grosso, Mato Grosso do Sul, Minas Gerais and São Paulo	MT, MS, MG and SP	Registered	Agriculture/ Biogas	AM16	475
AWMS GHG Mitigation Project BR05-B-13, Goias, Minas Gerais	GO and MG	Registered	Agriculture/ Biogas	AM16	838
AWMS GHG Mitigation Project BR05-B-14, Espirito Santo, Minas Gerais, and São Paulo	ES, MG and SP	Registered	Agriculture/ Biogas	AM16	356
AWMS GHG Mitigation Project BR05-B-15, Paraná, Santa Catarina and Rio Grande do Sul	PR, SC and RS	Registered	Agriculture/ Biogas	AM16	305
AWMS GHG Mitigation Project BR05-B-16, Bahia, Goiãs, Mato Grosso etc	SP	Registered	Agriculture/ Biogas *flare*	AM16	593
AWMS GHG Mitigation Project BR05-B-17. Espirito Santo, Mato Grosso do Sul, and Minas Gerais	ES and MT	Registered	Agriculture/ Biogas	AM16	271
ECOINVEST – MASTER Agropecuária – GHG capture and combustion from swine farms in Southern Brazil	GO	Registered	Agriculture/ Biogas	AM6	426
AWMS Methane Recovery Project BR06-S-24, Mato Grosso and Mato Grosso do Sul, Brazil	MS	Registered	Agriculture/ Biogas	AMS-III.D.	137
AWMS Methane Recovery Project BR06-S-23, Mato Grosso and Goias, Brazil	MT and GO	Registered	Agriculture/ Biogas	AMS-III.D.	84
AWMS Methane Recovery Project BR06-S-19, Goias, Brazil	GO	Registered	Agriculture/ Biogas	AMS-III.D.	128
AWMS Methane Recovery Project BR06-S-18, Parana, Rio Grande do Sul, and Santa Catarina, Brazil	PR, SC and RS	Registered	Agriculture/ Biogas	AMS-III.D.	148
AWMS Methane Recovery Project BR06-S-21, Goias, Brazil	GO	Registered	Agriculture/ Biogas	AMS-III.D.	115

AWMS Methane Recovery Project BR06-S-25, Minas Gerais, Brazil	MG	Registered	Agriculture/ Biogas	AMS-III.D.	181
AWMS Methane Recovery Project BR06-S-22, Minas Gerais, Brazil	MG	Registered	Agriculture/ Biogas	AMS-III.D.	82
AWMS Methane Recovery Project BR06-S-20, Minas Gerais, Brazil	MG	Registered	Agriculture/ Biogas	AMS-III.D.	67
AWMS Methane Recovery Project BR06-S-26, Minas Gerais, Brazil	MG	Registered	Agriculture/ Biogas	AMS-III.D.	67
AWMS Methane Recovery Project BR06-S-27, Goias, Brazil	Goiás	Registered	Agriculture/ Biogas	AMS-III.D.	60
AWMS Methane Recovery Project BR06-S-29, Sao Paulo, Brazil	SP	Registered	Agriculture/ Biogas	AMS-III.D.	122
AWMS Methane Recovery Project BR06-S-28, Santa Catarina, Brazil	SC	Registered	Agriculture/ Biogas	AMS-III.D.	23
AWMS Methane Recovery Project BR06-S-30, Mato Grosso and Mato Grosso do Sul, Brazil	MT and MS	Registered	Agriculture/ Biogas	AMS-III.D.	50
AWMS Methane Recovery Project BR06-S-33, Minas Gerais and Sao Paulo	MG and SP	Registered	Agriculture/ Biogas	AMS-III.D.	41
AWMS Methane Recovery Project BR07-S-34, Bahia, Espirito Santo, Minas Gerais, and Sao Paulo	BA, ES, MG and SP	Registered	Agriculture/ Biogas	AMS-III.D.	41
AWMS Methane Recovery Project BR07-S-31, Mato Grosso do Sul, Parana, Rio Grande do Sul, and Santa Catarina	MT, PR, SC and RS	Registered	Agriculture/ Biogas	AMS-III.D.	75
COTRIBÁ Swine Waste Management System Project	RS	Registered	Agriculture/ Biogas	AMS-III.D.	61
Amazon Carbon Swine Waste Management System Project 02	PR, SC, RS, GO and MT	Registered	Agriculture/ Biogas	AMS-III.D.	84

Name of project	State	Status	Type/sub-type	Methodology	$ktCO_2$
GHG Capture and Combustion From Swine Manure System	n.a.	Validation	Agriculture/ Biogas	AM6	322
SADIA OWNED FARMS - GHG capture and combustion from swine manure management systems in Brazil.	PR, SC, RS and MG	Validation	Agriculture/ Biogas	AM6	438
Ecoinvest – Agroceres PIC – GHG capture and combustion from a swine farm in Southeast Brazil	MG	Validation	Agriculture/ Biogas	AMS-III.D.	23
AWMS Methane Recovery Project BR06-S-32, Minas Gerais and São Paulo, Brazil	MG and SP	Validation	Agriculture/ Biogas	AMS-III.D.	63
Project of treatment and swine's' manure utilization at Ecobio Carbon - Swineculture Nº 1	SC	Validation	Agriculture/ Biogas	AMS-III.D.	135
Perdigão Sustainable Swine Production 02 – Methane capture and combustion	GO and SC	Validation	Agriculture/ Biogas *flare*	AMS-I.D.+AMS-III.D.	233
BRASCARBON Methane Recovery Project BCA-BRA-03	MG	Validation	Agriculture/ Biogas *flare*	AMS-III.D.	184
BRASCARBON Methane Recovery Project BCA-BRA-08	SP and PR	Validation	Agriculture/ Biogas *flare*	AMS-III.D.	184

BRASCARBON Methane Recovery Project BCA-BRA-02	SP	Validation	Agriculture/ Biogas *flare*	AMS-III.D.	188
BRASCARBON Methane Recovery Project BCA-BRA-05	MS	Validation	Agriculture/ Biogas *flare*	AMS-III.D.	182
BRASCARBON Methane Recovery Project BCA-BRA-07	MT and MS	Validation	Agriculture/ Biogas *flare*	AMS-III.D.	183
Project of treatment and swine's manure utilization at Ecobio Carbon - Swineculture Nº 4	MG	Validation	Agriculture/ Biogas	AMS-III.D.	126
Project of treatment and pig manure utilization at Ecobio Carbon – Swine Culture Nº 2"	SC	Validation	Agriculture/ Biogas	AMS-III.D.	117
Project of treatment and pig manure utilization at Ecobio Carbon - Swineculture Nº 3"	SC	Validation	Agriculture/ Biogas	AMS-III.D.	146
Project of treatment and pig manure utilization at Ecobio Carbon – Swine Culture Nº 5	SC	Validation	Agriculture/ Biogas	AMS-III.D.	125
Amazon Carbon Swine Waste Management System Project 03	MS	Registered	Agriculture/ Biogas	AMS-III.D.	58
Mitigation of the environmental passive through the management of the swine manure and renewable electricity generation	SC	Validation	Agriculture/ Energy generation	ACM10	598
Carroll's Foods do Brasil & LOGICarbon – GHG Emission Reductions from Swine Manure Management System, Diamantino, MT	MT	Validation	Biogas/ Energy generation	ACM10	255
Batavo Cooperativa Agroindustrial: Greenhouse emission reductions on swine production by means the installation of better waste management systems.	PR	Validation	Biogas/ Energy generation	AMS-II.D.	45

(*) In 2012.
(**)Defined as the CERs emitted due to the number of CERs expected in the same period.
(***) At end 2012.

Name of project	kCERs	kCERs expected (**)	Emissions success	Date of Registration	Installed energy (***)
Perdigão Sustainable Swine Production 01 – Methane capture and combustion					
GHG capture/combustion from swine manure man. systems at Faxinal dos Guedes and Toledo				30/01/06	
Granja Becker GHG mitigation project (NM34)	3	11	29%	9/12/2005	
AWMS GHG Mitigation Project BR05-B-01, Minas Gerais Brazil	54	172	31%	29/12/06	
AWMS GHG Mitigation Project BR05-B-03	175	607	29%	16/10/06	
AWMS GHG Mitigation Project BR05-B-02, Minas Gerais / São Paulo	124	482	26%	18/06/06	
AWMS GHG Mitigation Project BR05-B-04, Paraná, Santa Catarina, and Rio Grande do Sul	62	295	21%	9/7/2006	
AWMS GHG Mitigation Project BR05-B-05, Minas Gerais and São Paulo	81	245	33%	9/7/2006	
AWMS GHG Mitigation Project BR05-B-07, Mato Grosso, Minas Gerais, and Goiás	180	462	39%	25/05/06	
AWMS GHG Mitigation Project BR05-B-09	23	119	19%	18/06/06	
AWMS GHG Mitigation Project BR05-B-06, Bahía	2	15	15%	8/7/2006	
AWMS GHG Mitigation Project BR05-B-10, Minas Gerais, Goias, Mato Grosso, and Mato Grosso do Sul	48	248	19%	9/7/2006	
AWMS GHG Mitigation Project BR05-B-08, Paraná, Santa Catrina, and Rio Grande do Sul				10/9/2006	
AWMS GHG Mitigation Project BR05-B-11, Mato Grosso, Minas Gerais and São Paulo	29	147	20%	9/7/2006	
AWMS GHG Mitigation Project BR05-B-12, Mato Grosso, Mato Grosso do Sul, Minas Gerais and São Paulo	57	76	75%	11/9/2006	
AWMS GHG Mitigation Project BR05-B-13, Goias, Minas Gerais	121	301	40%	09/0706	
AWMS GHG Mitigation Project BR05-B-14, Espirito Santo, Minas Gerais, and São Paulo	35	97	36%	09/0706	
AWMS GHG Mitigation Project BR05-B-15, Paraná, Santa Catarina and Rio Grande do Sul	23	95	24%	9/7/2006	
AWMS GHG Mitigation Project BR05-B-16, Bahia, Goiãs, Mato Grosso etc	59	205	29%	15/07/06	
AWMS GHG Mitigation Project BR05-B-17. Espirito Santo, Mato Grosso do Sul, and Minas Gerais				30/09/06	
ECOINVEST – MASTER Agropecuária – GHG capture and combustion from swine farms in Southern Brazil				29/09/06	
AWMS Methane Recovery Project BR06-S-24, Mato Grosso and Mato Grosso do Sul, Brazil				1/2/2008	

Name of project	kCERs	kCERs expected (**)	Emissions success	Date of Registration	Installed energy (***)
AWMS Methane Recovery Project BR06-S-19, Goias, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-18, Parana, Rio Grande do Sul, and Santa Catarina, Brazil				5/6/2008	
AWMS Methane Recovery Project BR06-S-21, Goias, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-25, Minas Gerais, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-22, Minas Gerais, Brazil				7/4/2008	
AWMS Methane Recovery Project BR06-S-20, Minas Gerais, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-26, Minas Gerais, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-27, Goias, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-29, Sao Paulo, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-28, Santa Catarina, Brazil				1/2/2008	
AWMS Methane Recovery Project BR06-S-30, Mato Grosso and Mato Grosso do Sul, Brazil				17/03/08	
AWMS Methane Recovery Project BR06-S-33, Minas Gerais and Sao Paulo				10/4/2008	
AWMS Methane Recovery Project BR07-S-34, Bahia, Espirito Santo, Minas Gerais, and Sao Paulo				10/4/2008	
AWMS Methane Recovery Project BR07-S-31, Mato Grosso do Sul, Parana, Rio Grande do Sul, and Santa Catarina				5/6/2008	
COTRIBÁ Swine Waste Management System Project				12/1/2009	
Amazon Carbon Swine Waste Management System Project 02				10/3/2009	
GHG Capture and Combustion From Swine Manure System					
SADIA OWNED FARMS - GHG capture and combustion from swine manure management systems in Brazil.					
Ecoinvest – Agroceres PIC – GHG capture and combustion from a swine farm in Southeast Brazil					
AWMS Methane Recovery Project BR06-S-32, Minas Gerais and São Paulo, Brazil					
Project of treatment and swine's' manure utilization at Ecobio Carbon - Swineculture Nº 1					
Perdigão Sustainable Swine Production 02 – Methane capture and combustion					
BRASCARBON Methane Recovery Project BCA-BRA-03					

Name of project	kCERs	kCERs expected (**)	Emissions success	Date of Registration	Installed energy (***)
BRASCARBON Methane Recovery Project BCA-BRA-02					
BRASCARBON Methane Recovery Project BCA-BRA-05					
BRASCARBON Methane Recovery Project BCA-BRA-07					
Project of treatment and swine's manure utilization at Ecobio Carbon - Swineculture Nº 4					
Project of treatment and pig manure utilization at Ecobio Carbon – Swine Culture Nº 2"					
Project of treatment and pig manure utilization at Ecobio Carbon - Swineculture Nº 3"					
Project of treatment and pig manure utilization at Ecobio Carbon – Swine Culture Nº 5					
Amazon Carbon Swine Waste Management System Project 03				10/3/2009	
Mitigation of the environmental passive through the management of the swine manure and renewable electricity generation					1,0
Carroll's Foods do Brasil & LOGICarbon – GHG Emission Reductions from Swine Manure Management System, Diamantino, MT					1,8
Batavo Cooperativa Agroindustrial: Greenhouse emission reductions on swine production by means the installation of better waste management systems.					

(*) In 2012.
(**)Defined as the CERs emitted due to the number of CERs expected in the same period.
(***) At end 2012.

7.2. Government programs, plans and actions in the waste sector

Table 29 below summarizes the main current government programs, plans, and actions in the waste sector being undertaken in 2009.

7.3. Brazilian regulatory framework for the waste sector (in force in 2009)

Table 29 - Government programs, plans and actions in the waste sector

Reference	Management	Description
Basic Sanitation Pact	Ministry of Cities–National Environmental Sanitation Secretariat	The Basic Sanitation Pact is in keeping with the general thrust of the PLANSAB (Programa Nacional de Saneamento Básico / National Basic Sanitation Program) in terms of content, assumptions, main challenges, structural elements, themes and priority goals of this Plan.
Terms of Reference–Outlook for Basic Sanitation in Brazil	Ministry of Cities–National Environmental Sanitation Secretariat	The Ministry of Cities opened a public bid (for proposals to be sent by 30 March 2009) for the elaboration of a study on the Outlook for Basic Sanitation in Brazil. This study should contain a diagnosis of the sanitation situation in Brazil related to the four basic components, and is intended to serve as a basis, together with the Basic Sanitation Pact, for formulating the PLANSAB. The deadline for completion of the study is six months from the date of signature of the contract.
Social Action in Sanitation Program (PASS-BID)	Ministry of Cities–National Environmental Sanitation Secretariat	The aim of this program is to increase the coverage and improve the quality of environmental sanitation services in urban areas, focused on water supply, sewerage, upgrading administrative capacities of service providers (working in the Program), health and environmental education, capability building for environmental entities and support for studies related to the development of policies for the sanitation sector. International financing resources are targeted at small and medium-sized municipalities in the north, northeast, centre-west regions, plus Espirito Santo and the north of the state of Minas Gerais - all of which have serious basic sanitation deficits.
Programa Saneamento para Todos ("Sanitation Program for All")	Ministry of Cities–National Environmental Sanitation Secretariat	The Programa Saneamento para Todos aims to improve health and quality of life conditions of the population through actions targeted at reducing deficits in the basic sanitation sector in urban areas. The program provides funding for undertakings in the areas of water supply, sewerage, integrated sanitation, institutional development, rain water management, solid waste management, handling of construction and demolition rubble, conservation and recovery of water sources and, finally, studies and projects. The resources for contracting this work originate with the FGTS, on the basis of Normative Directive 33 dated 1 August 2007, which provides the regulatory basis for the procedures and measures relating to credit operations within the context of the Programa Saneamento para Todos/ Mutuários Privados e Mutuários Sociedades de Propósito Específico, formed by Resolution nº 476 of 31 May 2005, modified by Resolution nº 491 of 14 December 2005 -both under the aegis of the Supervisory Council (Conselho Curador) of the Length of Service Guarantee Fund (FGTS).

Reference	Management	Description
Environmental Education and Social Mobilization In Sanitation Program (PEAMSS)	Ministry of Cities–National Environmental Sanitation Secretariat	The PEAMSS embraces the principles, guidelines and action lines for guiding the interventions concerned with environmental education and social mobilization with regard to sanitation. The aim of the program is to encourage liaisons among different stakeholders including public authorities, institutions, the private sector, universities, and members of civil society who will undertake activities targeted at developing sanitation-related environmental education in response to the federal government programs and investments.
Modernization Program for the Sanitation Sector (PMSS)	Ministry of Cities–National Environmental Sanitation Secretariat	The PMSS program is designed to train technical staff, control water losses, improve the effectiveness of public sanitation service providers, and contribute to broadening coverage of water and sewage services, as well as to undertake studies targeted at establishing the National Sanitation Information System (SNIS). Funding, provided by the World Bank, the Federal Government, and Sanitation Service Providers, is targeted at municipalities, states, water and sewage companies and regulatory agencies. In May 2003, a study called "Assessing the scale of investment needs for universalizing water supply and sewage collection/treatment in Brazil" was published and disseminated. The estimates were calculated on the basis of data for year 2000 and future projections have been made for 2010, 2015 and 2020. The demand for sanitation services together with estimates of associated costs were surveyed state-by-state and for the five large geographic regions of Brazil
Urban Water and Sewage Services Program	Ministry of Cities–National Environmental Sanitation Secretariat	The aim of this program is to provide support for the installation and extension of water supply and sewage collection/treatment systems in municipalities with populations of over 50,000 inhabitants. Financing is provided within the General Budget of the Union (OGU).
Technical assistance project for PROSANEAR (PAT PROSANEAR)	Ministry of Cities–National Environmental Sanitation Secretariat	The PAT PROSANEAR aims to prepare and execute studies and projects in the environmental sanitation area and to focus on training and institutional development, social strengthening, enforcement and evaluation in a quest for improving the living conditions in slums.

Reference	Management	Description
National Anti-Water Waste Program (PNCDA)	Ministry of Cities– National Environmental Sanitation Secretariat	The PNCDA involves a partnership between stakeholders in the sanitation sector, NGOs, normative entities (ABNT, INMETRO, etc.), manufacturers of materials and equipment, service providers in both the public and private sectors, universities, research centers, and other bodies at the federal level, with the aim of undertaking water conservation measures and improving the energy supply efficiency of sanitation systems.
Priority Investment Projects– PPI – for interventions in slums	Ministry of Cities– National Environmental Sanitation Secretariat/ National Housing Secretariat	This manual contains the guidance needed for the process of presentation, selection and analysis of proposals for interventions in slums, which is one of the priority investment projects (PPI) of the Federal Government's Growth Acceleration Program (PAC). These interventions are targeted at undertaking the activities needed for land and property ownership regularization, improving safety, health and living conditions of people living in substandard accommodation in unsuitable areas, with a view to improving conditions in situ or relocating people from such areas employing integrated housing, sanitation and social inclusion initiatives.
MSW (RSU) Program	Ministry of Cities– National Environmental Sanitation Secretariat together with other ministries, BNDES and FUNASA.	The MSW Program provides support for undertaking studies and design plans, projects, and for installing, extending or improving services concerned with urban cleansing, collection, treatment and final disposal of MSW. The program involves improving or establishing sanitary landfills, recycling and composting centers, providing equipment for waste collection and handling, improving dumpsites, boosting social insertion for waste scavengers, organizing trash worker cooperatives, and undertaking associated social work, capacity building and institutional development in the sanitation field. Financing is provided within the General Budget of the Union (OGU).
CDM project for reducing gas emissions generated in solid waste disposal	Ministry of Cities– National Environmental Sanitation Secretariat / Environment Ministry/ World Bank	This project is targeted at 200 of the most densely populated municipalities in Brazil, housing over half of the country's population and responsible for around 60 percent of all municipal solid waste. Project activities are focused on contributing to the sustainable development of urban areas, employing the CDM as a useful tool for undertaking economic, social and environmental programs. The program also focuses on using biogas produced by landfills for power generation, eradication of garbage dumps, actions to bolster social inclusion and to free families from waste scavenging, providing environmental and social benefits to those involved in this occupation. Funding for this project was provided by the World Bank and the Japanese Government.

Reference	Management	Description
"Pró-Municípios" program	Ministry of Cities	The purpose of this program is to undertake or improve infrastructural work in small, medium and large municipalities in terms of urban infrastructure, water supply, sewage networks, drainage, elaboration of urban development master plans, improving urban traffic conditions, producing or acquiring housing units, and upgrading slums. Financing is provided within the General Budget of the Union (OGU).
National Environment Fund (FNMA)	Environment Ministry	The National Environment Fund (FNMA) was established 19 years ago and is currently Brazil's main source of financing for environmental purposes and an important partner for Brazilian society in the quest for quality of life and environmental improvements. Supporting efforts by civil society and governmental entities and organizations targeted at recovering, conserving and preserving the environment, the FNMA has become a reference for the transparent and democratic process involved in selecting projects. Its decentralized management procedures provides a trickle-down effect which has had a positive impact on the treatment of environmental problems throughout the country including those involving solid waste.
Program to de-pollute River Basins (PRODES)	Environment Ministry/ National Water Agency-ANA	The PRODES provides financial encouragement for installing new sewage treatment plants or extending existing ones. This program pays by results, remunerating service providers who dispose of and treat sewage according to the conditions set forth in the Payment for Treated Sewage That.
"Brasil Joga Limpo" Program	Environment Ministry	"Brasil Joga Limpo" is a Federal Government-run program aimed at implementing projects under the aegis of the national environmental policy according to the criteria and measures established by the National Environment Fund (FNMA). The program operates with funds provided by the OGU, allocated to municipalities and state and municipal concession holders in accordance with work stages executed and proven. The main objectives of the program are to elaborate the Integrated Management Plan for Solid Waste (installing sanitary landfills, treatment units, final disposal works and encouraging selective collection and dump site renewal).
Growth Acceleration Program (PAC)	Planning, Budget and Management Ministry	The principal aim of the PAC is to provide a boost to development, promote economic growth, job generation and improve living conditions of the Brazilian population. The 'sanitation' theme forms part of the investments scheme of the PAC under the social and urban infrastructure rubric. The PAC-Sanitation segment is targeted at improving and broadening access by the Brazilian population to basic sanitation services by introducing institutional type changes, improving management mechanisms and increasing infrastructure investments. The target of the PAC is to provide water supply to 7 million households, sewage to 7.3 million and improved solid waste collection for 8.9 million households.

Reference	Management	Description
Organization and development of solid waste cooperatives	Ministry of Labor and Employment	The efforts of this ministry are directed towards economic feasibility studies related to developments concerned with the treatment of solid waste and to provide financial subsidies for forming cooperatives working in the solid waste environment. The aim is also to encourage initiatives for building cooperative ventures in the context of the production chains related to solid waste and to liaise with other ministries with a view to avoiding overlapping activities and to ensure optimum use of resources.
Basic Sanitation Research Program (PROSAB)	Ministry of Science and Technology /Studies and Project Financing Organ (FINEP)	The goal of this research program is to support the undertaking of research on different technologies in the areas concerned with water supply, sewerage and solid waste which are easy to apply at low cost in terms of installation, operation and maintenance and which can result in improved living conditions for the Brazilian population, especially the poorest members.
FUNASA/PAC	National Health Foundation/Ministry of Cities/ National Integration Ministry	This FUNASA program (using funds provided under the PAC, prioritizes sanitation improvements for municipalities with populations of up to 50,000 and targets initiatives for improving water supply systems and solid waste and sewage collection and disposal for households.
Environmental sanitation and water resources projects undertaken by BNDES	National Social and Economic Development Bank	This program aims to support public or private investment projects aimed at the universalization of access to basic sanitation services and the recovery of environmentally degraded areas by encouraging integrated management of water resources and the adoption of river basins as basic planning units. Investments are directed to the following areas: water supply, sewage, industrial effluent and waste treatment, solid waste treatment, water resources administration, recovery of environmentally degraded areas and the de-pollution of water basins in areas where the appropriate committees have already been established.
Integrated Urban Multisectoral Projects (PMI)	National Social and Economic Development Bank	This is a set of projects covering planning and operations by municipal agents in a number of different sectors with a view to contributing to solving structural problems in urban centers. The projects to be financed by BNDES can also be targeted at specific sectors such as transport or sanitation, providing these fall within the broader plans of the municipal authorities. Among projects eligible for financing are those related to environmental sanitation (water supply, sewerage, solid waste treatment and urban drainage).
		Law 11.478 of 29.5.2007, published in the Official Gazette of 30.5.2007, established the FIP- IE, "Fundo de Investimento em Participações em Infra-Estrutura " (Infrastructure Investment Fund).

7.4 Brazilian regulatory framework for the waste sector (in force in 2009)

Table 30 - Federal level legal rulings applicable to the waste sector

Legal rulings	Description
1988 Federal Constitution	Federal Constitution of Brazil
Law 11.445 of 5.1.2007 published in the Official Gazette (DOU) of 8.1.2007	Sets forth national guidelines for basic sanitation; modifies Laws 6.766 of 19 December 1979, 8.036, of 11 May 1990, 8.666 of 21 June 1993 and 8.987 of 13 February 1995; repeals Law 6.528 of 11 May 1978; and makes other provisions. Received vetoes. Decree Memorandum of 6.8.2007 provides regulatory framework for the law (still not issued). Bills and legal opinions required prior to final approval
Bill 1.991-2007	Establishes the National Solid Waste Policy and makes other provisions. Explanation of reasons.
Law 11.107 of 6.4.2005 published in the Official Gazette (DOU) of 18.1.2007	Deals with general norms for contracting public consortia and makes other provisions. Received vetoes. Decree 6.017 of 17.1.2007 regulates Law 11.107. Legal Opinions.
Law 11.079 of 30.12.2004 published in the Official Gazette (DOU) of 31.12.2004	Sets forth general public sector norms for bidding and contracting PPPs. Received vetoes
Law 10.257 of 10.07.2001 published in the Official Gazette (DOU) of 11.07.2001	Cities Statute - regulates Articles 182 and 183 of the Federal Constitution and sets down general guidelines for urban policy, and makes other provisions. Received vetoes
Law 9.984 of 17.7.2000 published in the Official Gazette (DOU) of 18.7.2000	Addresses creation of the National Waters Agency - ANA, a federal body designed to implement the National Water Resources Policy and coordinate the National System for Water Resources Management, and introduces other measures. Received vetoes.
Law 9.795 of 27.04.1999 published in the Official Gazette (DOU) of 28.01.1999	Addresses question of environmental education, establishes the National Environmental Education Policy and provides for other measures. Received vetoes
Law 9.433 of 8.1.1997 published in the Official Gazette (DOU) of 9.1.1997	Establishes the National Water Resources Policy, creates the National System for Water Resources Management and regulates Clause XIX of Article 21 of the Federal Constitution, and modifies Article 1º of Law 8.001 of 13 March 1990, which updated Law 7.990 of 28 December 1989. With vetoes

Legal rulings	Description
Law 9.074 of 7.7.1995 published in the Official Gazette (DOU) of 8.7.1995 – Extra Ed. republished on 28.9.1998	Establishing norms for awarding and extending concessions and permits for delivering public services, and a series of other measures. Received vetoes. Text compiled.
Law 8.987 of 13.2.1995 published in the Official Gazette (DOU) of 14.2.1995 and republished in the DOU of 28.9.98	Deals with the regime for awarding concessions and permits for public services delivery foreshadowed under Article 175 of the Federal Constitution, and a series of other measures. Received vetoes. Text compiled.
Law 8.666 of 21.6.1993 published in the Official Gazette (DOU) of 22.6.1993 and republished in the DOU of 6.7.1994	Regulates Article 37, Clause XXI, of the Federal Constitution, sets forth norms for public administration bidding and contracts and a series of other measures. Received vetoes. Text compiled.
Law 8.080 of 19.9.1990 published in the Official Gazette (DOU) of 20.9.1990	Law of the SUS, covering conditions for health promotion, protection and recovery, as ell as the organization and functioning of relevant services, and establishes a series of other measures Received vetoes.
Law 8.078 of 11.9.1990 published in the Official Gazette (DOU) of 12.9.1990 - Extra Ed.	Consumer Protection Code and other measures. With vetoes. Text compiled . Decree 5.903 of 20.9.2006 regulates the Law
Law 7.797 of 10.7.1989 published in the Official Gazette (DOU) of 11.7.1989	Establishes the National Environmental Fund and recommends a series of other measures.
Law 6.938 of 31.8.1981 published in the Official Gazette (DOU) of 2.9.1981	Deals with the National Environment Policy: its aims and application/formulation mechanisms, and introduces a series of other measures. Text compiled . Decree 99.274 of 6.6.1990 regulates the Law. Decree 99.274 of 6.6.1990 – Text compiled.

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